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Section III.—Botany
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All communications relating to this Journal should be addressed to the Dean of the Faculty of Science, University of Tokyo.

ON RELATIONSHIP BETWEEN THE PROVENANCES AND THE DEPOSITIONAL BASINS, CONSIDERED FROM THE HEAVY MINERAL ASSOCIATIONS OF THE UPPER CRETACEOUS AND TERTIARY FORMATIONS IN CENTRAL AND SOUTHEASTERN HOKKAIDO, JAPAN

By

Azuma IIJIMA

With Three Plates

Contents

Abstract

The Hidaka, Kitami and Yubari mountains, the roof of Hokkaido, run parallel from north to south in its central part. They express the past intense orogenic movement from Jurassic to Tertiary, called the Hidaka orogeny. Its synorogenic to post-orogenic sediments are presented by the Upper Cretaceous and Tertiary formations in the central and southeastern part of the island.

In the first place, the heavy mineral assemblages of these formations are studied. They indicate close relation with the developmental stages of the Hidaka orogenic movement. The connection between the provenances and the depositional basins are then considered principally from them. A palaeogeographical map is tentatively prepared for each one of eight different ages, ranging from Upper Cretaceous to Upper Miocene.

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Introduction

It has been done, in other countries, statistically to prove the provenance as well as the process of transportation and deposition of sediments from the heavy mineral composition of sedimentary rocks. In our country, however, quantitative studies on sedimentary rocks have little been made, although qualitative works have been done in such a manner as a study of kinds of pebbles in conglomerates or of rock fragments and mineral grains in sandstones, to ascertain their background. There are some reason why one feels difficulty in treating sedimentary rocks quantitatively: for instance, geological structure is very complicated by repeated orogenic movements; depositional basins show very rapid rise and fall, so that persistence of strata is very poor. In view of such a complicated structure like Japan, it is significant and necessary to execute statistical studies on sedimentary rocks, so as to understand its geological history more completely. Of course, the stratigraphical and palaeontological methods must be used at the same time.

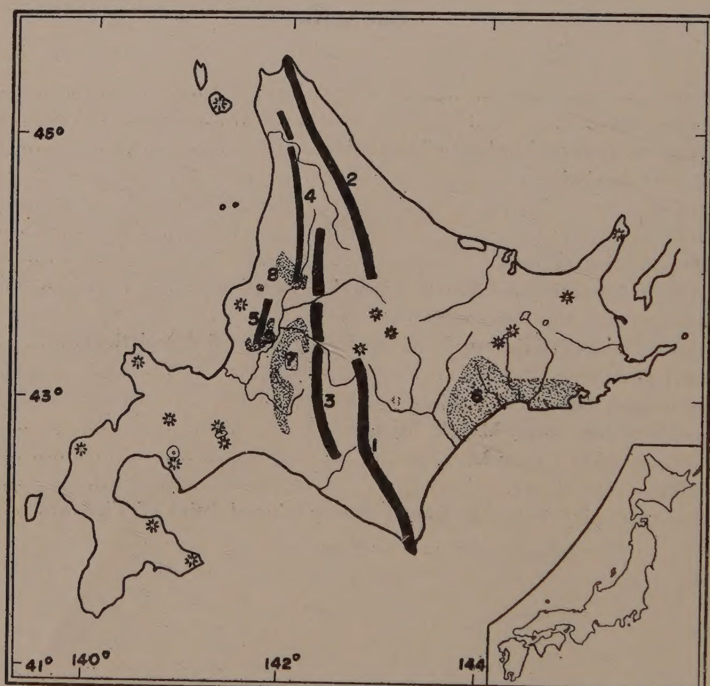

Fig. 1. Index and topographical map.

1. the Hidaka Mountains
2. the Kitami Mountains
3. the Yubari Mountains
4. the Teshio Mountains
5. the Kaboto Mountainous Land
6. the Kushiro Coal-field
7. the Ishikari Coal-field
8. the Rumoi Coal-field

* Quaternary volcano

The study of sedimentary rocks must be pursued on their significance of historical vicissitude as well as on their petrological character. Because, sedi-

mentary rocks are products of any tectonic movement and their characters vividly reflect the nature of the movement both in the depositional basin and in the provenance. Therefore, the statistical study of mineral associations of sedimentary rocks is one of the most valuable means to know relations between them.

Since 1952, the writer has surveyed the Palaeogene coal fields in Hokkaido, and studied the heavy minaral associations of the Upper Cretaceous and Tertiary formations. These coal fields extend on both west and east sides of the Hidaka Mountains which were formed by the orogenic movement from Jurassic to Tertiary. The Ishikari, Kabato and Rumoi coal fields on the west are the deep depositional basin formed in the front of the orogenic arc, while, the Kushiro coal field on the east is formed in the inner basin behind the arc. The Upper Cretaceous and Tertiary sediments in these coal fields present the synorogenic to post-orogenic nature. Their characters and heavy mineral associations are considerably different from each other, but show a very close relation with the development of the Hidaka orogeny.

In this thesis, the heavy mineral compositions and their probable origins are made clear at the first place. The connection between the depositional basins and the provenances are then considered, using palaeogeographical maps. Finally, it is discussed synthetically that the geological history of central and southeastern Hokkaido during the Upper Cretaceous to Tertiary period.

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A Brief Note on General Geology of Hokkaido

Before going further, a brief note on general geology of Hokkaido is given here.

Hokkaido is divided into four geological units, *i.e.*, the southwestern, northeastern, central and southeastern parts (Fig. 2).

Southwestern Hokkaido is so-called the "Tertiary Green-tuff region." It is a Miocene "geosynclinal" area with a violent volcanic activity. A huge volume of the Neogene sedimentary, pyroclastic and volcanic rocks are lying on the Palaeozoic and granitic basement.

Northeastern Hokkaido is also the "Tertiary Green-tuff area" extending to the Kuril Islands. Vast volume of sediments with volcanic and pyroclastic rocks were deposited since the Middle Miocene age on the Palaeozoic and Cretaceous terrain.

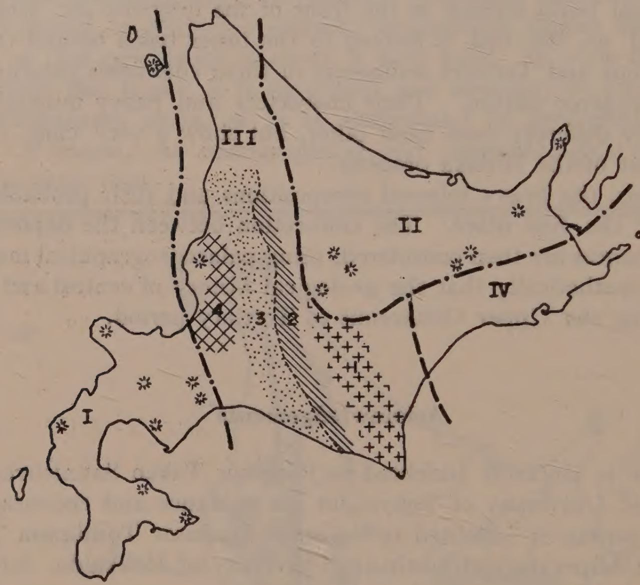


Fig. 2. Tectonic units of Hokkaido.

I The "Green-tuff region" in southwestern Hokkaido
II "The Green-tuff region" in northeastern Hokkaido
III The Yezo arc in central Hokkaido
1. Hidaka axial zone
2. Kamuikotan metamorphic zone
3. Ishikari-Rumoi zone
4. Kabato mountainous land
IV Southeastern Hokkaido

Central Hokkaido belonging to the Yezo Arc was the active site of the Hidaka orogeny during the Jurassic to Tertiary periods——the Alpine orogenic movement. It is divided into three parallel zones extending from north to south. The Hidaka axial zone is composed of the Palaeozoic Hidaka group, migmatite, and many intruding bodies of diabase, gabbro, olivine-gabbro, gneissose gabbro, amphibolite, granite and gneissose granite with hornfels. The Kamuikotan zone, running parallel west of the axial zone, consists of the Jurassic to Lower Cretaceous formations and their peculiar metamorphic facies thrust in the front of the Hidaka zone. The latter is crystalline schist and phyllite formed under low-graded dynamo-metamorphism with a large amount of ultrabasic rocks, which intruded during or immediately after the metamorphism. The Jurassic formation

is composed of diabase, pillow lava, schalstein, chert, sandstone and siltstone. The Ishikari-Rumoi zone is a synclinal part west of the Kamuikotan zone. Repeated transgression and regression during the Cretaceous to Tertiary periods laid down thick marine and non-marine terrigenous sediments, intercalating many productive coal seams and oil-bearing formations. This zone has a very complicated geological structure, characterized by large-scale overturned folds and overthrusts which are probably caused by intense horizontal compression from the east. The Kabato Mountains is composed of the "Palaeozoic" and granitic basement with overlying blanket of the Palaeogene continental sediments.

Fig. 3. Geological map of the Hidaka Mountains, after M. MINATO, K. YAGI, and M. HUNAHASHI (1956).

1: Quaternary deposits. 2: Neogene Tertiary.
3: Cretaceous formation.
4: Kamuikotan metamorphic complex.
5: So-called Hidaka system, Jurassic and older complex.
6: Hornfels. 7: Gneiss
8: Migmatite. 9: Granitic migmatite.
10: Gneissose granite. 11: Granite.
12: Gabbro amphibolite. 13: Gneissose gabbro.
14: Gabbro. 15: Olivine Gabbro.
16: Peridotite. 17: Quaternary volcanics.
18: Fault. *Kr*: Karikachi pass.
P: Pipairo river. *T*: Tottabetsu river.
S: Satsunai river. *K*: Mt. Kamui.
R: Mt. Rakko. *Ob*: Obihiro.
O: Oshirabetsu. *S*: Shoya.
E: Erimo. *H*: Horoman.

Southeastern Hokkaido is to be reckoned as a quasi-inner basin behind the Hidaka orogenic zone. The Tertiary formation lies unconformably on the Upper Cretaceous. Its lower-half part (the Upper Palaeogene) is an alternation of continental, brackish and marine terrigenous sediments, interbedded a little pyroclastic rocks in the upper part and some minable coal seams, whil the upper-half (the Upper Neogene) mainly consists of marine pyroclastic and terrigenous sediments. These strata contain many intervals and also are thin and successive compared with those of the Ishikari-Rumoi zone. This area relatively shows a gentle folding structure or block mountain.

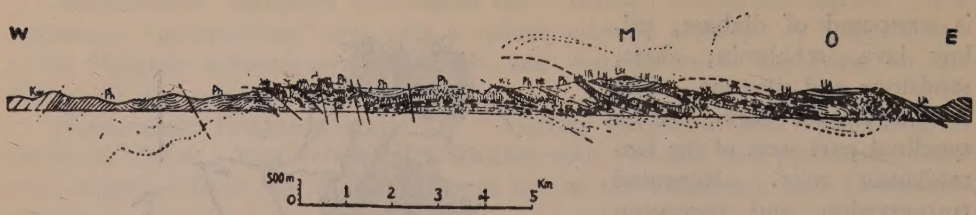


Fig. 4. Geologic section across the Southern Ishikari coal field, from east to west. (after M. MINATO et al, 1956)

Kw:	Neogene (Miocene) formation, Kawabata group of Molasse type	
Ph:	Poronai formation	
Wz:	Ikushumbetsu formation	Ishikari group
Wk:	Wakkanabe formation	
Yc:	Yubari coal-bearing formation	
Hk:	Horokabetsu formation	
Nc:	Noborikawa coal-bearing formation	
Lst & LH:	Hakobuchi formation	
UA:	Upper Ammonite formation	
O:	Oyubari "Klippe"	
M:	Maruyama "Klippe"	

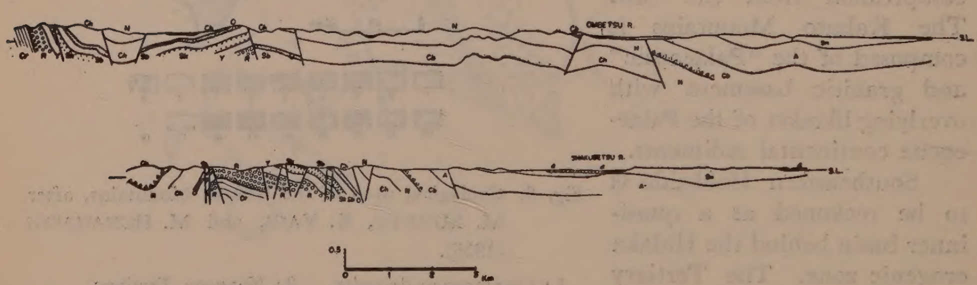


Fig. 5. Geologic sections across the Southwestern Kushiro coal field, from east to west.

a:	Alluvium	
Sn:	Shiranuka formation	Atsunai group
A:	Atsunai formation	
Cb:	Chokubetsu formation	
N:	Nuibetsu formation	Ombetsu group
Ch:	Charo formation	
O:	Omagari Sandstone	
Sb:	Shakubetsu coal-bearing formation	Urahoro group
Sk:	Shitakara formation	
Y:	Yubetsu coal-bearing formation	
R:	Rushin formation	
Cr:	Upper Cretaceous formation	

Heavy Mineral Analysis

1. Method

Mainly arenaceous rocks were used in this investigation because of abundance of heavy minerals in sand-size fraction and of predominance of sandstones in the formations studied.

Before loosening in a roller-mill for one half to one hour, hard-cemented

samples were crushed in an iron-mortar or a crusher. The coarser and finer fractions were removed in water by sieving on A.S.T.M. 50 and 250 mesh sieves respectively. Dry samples were weighed 3 to 10 grammes.[1] The authigenic material coatings were dissolved by gently boiling with 20%–HCl for 20 minutes. THOULET's solution (S.G.=2.9) was used as a heavy liquid medium. A special glass funnel with steep wall and two cocks was devised for heavy mineral separation (Fig. 6). The total amount of the heavy residues were weighed on a chemical balance. Residues with prolific pyrite were treated in conc–HNO_3.

Heavy residues obtained were mounted on glass slides in Canada balsam.[2] Then, the slides were studied, counting the number of heavy mineral grains under a polarized microscope with a mechanical stage.

Chromite is supplemented by the chemical test with a borax bead.

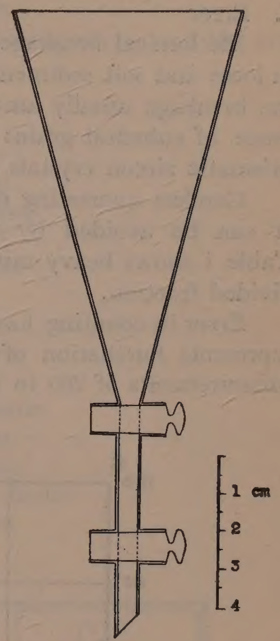


Fig. 6. Glass funnel for heavy mineral separation.

Table 1. Heavy Mineral Assemblage Calculated from Each of the Quartering Fractions of a Specimen.

Mineral Species	(1)	(2)
Biotite	3	2
Chlorite	3	–
Muscovite	1	–
Ores	66	56
Others	27	42
	100	**100**
Other Constituents		
Anatase	4.1	4.5
Augite	0.2	0.2
Brookite	1.4	1.8
Chromite	0.2	0.5
Garnet	13.3	13.5
Hornblende	0.2	–
Rutile	6.6	4.3
Sphene	1.6	1.1
Tourmaline	22.6	22.7
Zircon	48.5	50.4
Zircon (purple)	1.1	0.9
No. grains counted	437	442

1) A microsplitter of OTTO's type was used in quartering the samples. It was made of glass slide with twelve edges.

2) A small funnel with a flat apex and the microsplitter were used in quartering the residues (HUTTON, 1950).

2. Error

Mechanical breakage of heavy mineral grains during preparation is negligible in loose and soft sediments. It comes into question in hard-cemented rocks, but the breakage usually amounts to less than 3 percent of the total grains. Occurrence of euhedral grains of hornblende and hypersthene as well as long, slender prismatic zircon crystals proves little breakage.

Careless quartering of samples causes a serious error in the result obtained. It can be avoided by using microsplitter and moreover by careful treatment. Table 1 shows heavy mineral assemblages of a specimen, calculated from each divided fraction.

Error in counting has been estimated theoretically by DRYDEN (1935). Fig. 7 represents fluctuation of percentage with numbers of counted grains in practice. Measurements of 200 to 250 grains are normally sufficient.

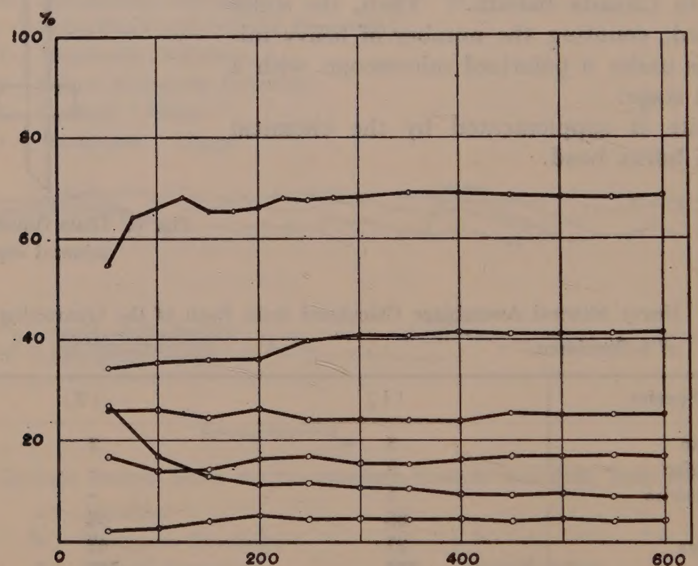


Fig. 7. Fluctuation of percentage with numbers of counted grains.

3. Representation of data

The final results obtained are represented in duplicate or triplicate system. Percentages of biotite, chlorite, muscovite[1], ores (black in reflected light) and other non-opaque minerals are calculated in the first place. Then, the others are represented in percentage. Percentage of leucoxene, limonite, hematite, pyrite, authigenic titania and other ingredients are calculated separately.

1) Micas and chlorites are excluded from other detrital non-opaque grains. Because, they have ±2.9 S.G. and their percentages are influenced by delicate operation in the course of separation.

4. Sampling localities and heavy mineral associations

Samples were collected from exposures, trenches, boring cores, and the walls of drifts. Sampling localities are as follows:

(1) The Kushiro coal field

Harutori Colliery
Shakubetsu Colliery
Yubetsu Colliery
Atsunai district
Rushin district
Urahoro district
Ombetsu district
Kamicharo district
Nuibetsu district
Shiranuka district

(2) The Ishikari coal field

Ashibetsu (Mitsui) Colliery
Akabira Colliery
Sunagawa Colliery
Naie Colliery
Chashinai Colliery
Bibai (Mitsubishi) Colliery
Pombetsu Colliery
Yayoi Colliery
Miruto Colliery
Yubari Colliery
Mayachi Colliery
Asahi Colliery
Momijiyama district
Takinoue district
Kuriyama district
Dammanosawa district
Utashinai district

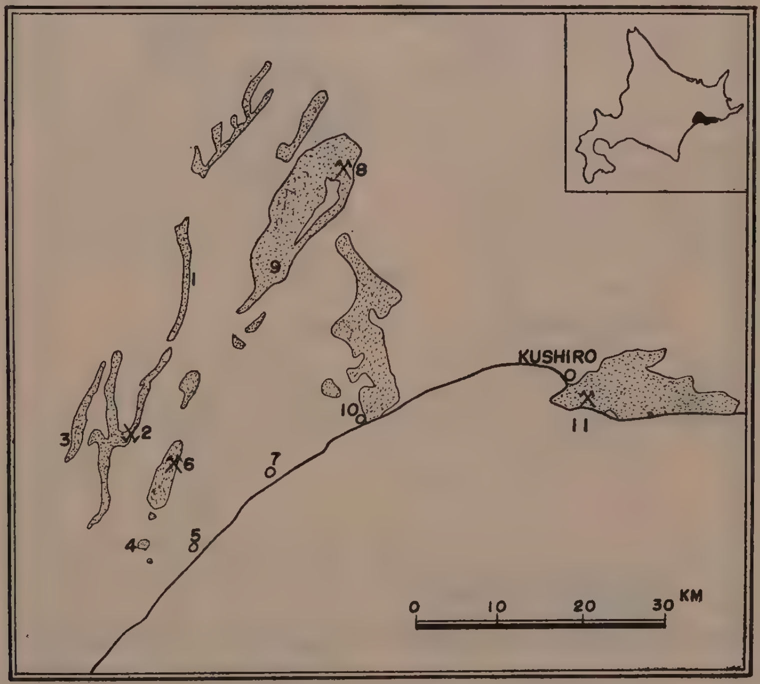


Fig. 8. Sampling localities in the Kushiro coal field. Dotted areas show the distribution of the Urahoro group.

1. Kamicharo
2. Urahoro Colliery (abandoned)
3. Rushin
4. Kamiatsunai
5. Atsunai
6. Shakubetsu Colliery
7. Ombetsu
8. Yubetsu Colliery
9. Nuibetsu
10. Shiranuka
11. Harutori Colliery

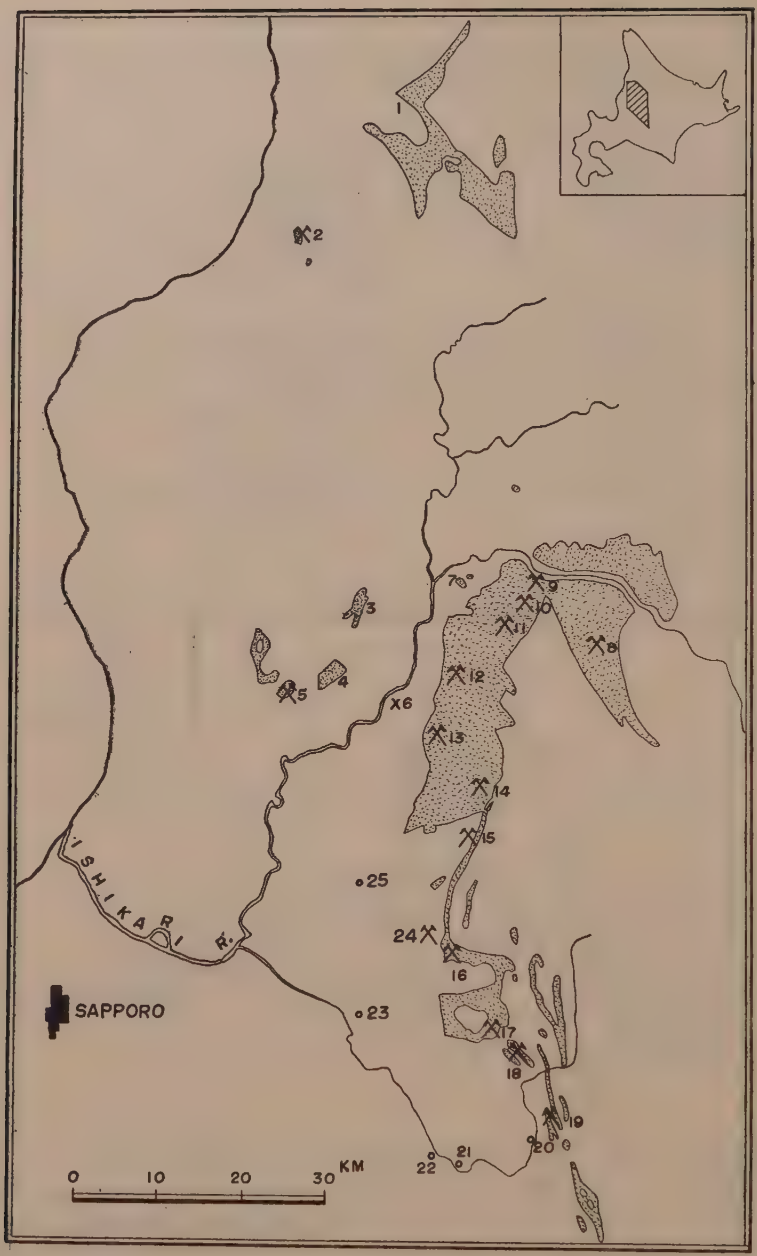


Fig. 9. Sampling localities in and around the Ishikari coal field. Dotted areas show the distribution of the Ishikari group.

1. Uryu district of the Rumoi coal field
2. Owada Colliery
3. Shintotsugawa district of the Kabato coal field
4. Urausu district of the Kabato coal field
5. Tsukigata Colliery
6. Naie drilling
7. Dammanosawa
8. Ashibetsu Colliery
9. Akabira Colliery
10. Utashinai Colliery
11. Sunagawa Colliery
12. Naie Colliery
13. Chashinai Colliery
14. Bibai Colliery
15. Pombetsu Colliery
16. Miruto Colliery
17. Yubari Colliery
18. Heiwa Colliery
19. Mayachi Colliery
20. Momijiyama
21. Takinoue
22. Kawabata
23. Kuriyama
24. Asahi Colliery
25. Iwamizawa

(3) The Ishikari Plain
Naie district
(4) The Kabato coal field
Tsukigata Colliery
Shintotsugawa-Urausu district
(5) The Rumoi coal field
Owada Colliery Tappu district

Each of the locations, horizons, and heavy mineral associations is listed in detail as an appendix.

Relationship between the Provenances and the Depositional Basins Considered from the Heavy Mineral Associations

1. Upper Cretaceous age

Upper Cretaceous system in Hokkaido is divided into the Gyliak, Urakawa, and Hetonai series in an ascending order. Each heavy mineral association of the series is shown in Table 2 and 3.

The associations in Central Hokkaido are nearly unchanged through the Gyliak and Urakawa series. They consist of six suites:

i) biotite-garnet-rutile-sphene-tourmaline-zircon-ores,
ii) augite-epidote-sphene-ores,
iii) augite-hypersthene-hornblende-ores,
iv) zircon (corroded and often enclosed by volcanic glass)-biotite,
v) purple zircon-rounded grains of zircon, tourmaline, rutile etc.,
vi) zircon (overgrowth).

They are originated from granite, diabase and schalstein, andesite, liparite, older sedimentary rocks, and contaminated granite, respectively.

The seventh suite is added in the Hetonai series:

Fig. 10. Palaeogeographical Map in Upper Cretaceous. The hatched area shows marine.

vii) chromite-magnetite.

It is likely derived from ultrabasic rocks, intruding into the Kamuikotan zone. The first granite-origin suite increases as the second diabase-origin one decreases.

The heavy mineral assemblages of the Upper Cretaceous formations in Southeastern Hokkaido, on the other hand, are composed of the next four suites during the Urakawa-Hetonai series:

i) biotite-garnet-hornblende-rutile-sphene-tourmaline-zircon-ores,
ii) augite-epidote-sphene-ores,
iii) augite-hypersthene-hornblende-ores,
iv) rounded grains of zircon, rutile etc.

They are brought from granodiorite, diabase and schalstein, andesite, and older sedimentary terrain, respectively.

Palaeogeography during the Upper Cretaceous age is pictured in Fig. 10. Hokkaido is under sea water except the southwestern and northeastern parts.

Table 2. Heavy Mineral Assemblages of the Gyliak and Urakawa Series.

	Gyliak		Urakawa				
	(1)	(2)	(3)	(4)	(5)	(6)*	(7)*
Biotite	5	1	3	3	1	14	15
Chlorite	2					14	4
Muscovite				1			1
Ores	3	7	26	4	18	7	24
Others	90	92	71	92	80	65	56
	100	100	100	100	100	100	100
Other Constituents							
Allanite	2			1			1
Anatase		tr	1	1			
Augite		4		1	71	tr	5
Epidote		69	60	39	4	69	61
Garnet (colorless)	12	14	7	18			5
Garnet (colored)	3	2	2	2			
Hornblende[1]				2	23	10	13
Hornblende (brown)	2				1		
Hypersthene	6			3			1
Rutile	9	tr	1	1			
Sphene	15	4	3	15			3
Tourmaline[2]	1	1	1	6	tr		1
Tourmaline[3]			1	1			
Tourmaline[4]		1		1			
Zircon (colorless)	50	4	22	6	1	21	9
Zircon (pink)	1		tr				
Zircon (brown)				tr			
Zircon (purple)	1	tr	tr				
Zircon (rounded)			1	3			1
Hematite	6						
Opaques	30	33	24	6	5	1	10
Pyrite	4	13	10	14		85	
Authigenic TiO_2	2						
Others	58	54	66	80	95	14	90
	100	100	100	100	100	100	100
Heavy mineral index	0.06	0.32	0.43	0.14	0.94	0.05	0.76

(1) Bibai, (2) Yubari, (3) Rumoi, (4) Yubari, (5) Urahoro,
(6) Nuibetsu, (7) Harutori

1. brownish green, 2. green-purple, 3. green, 4. brown

* May be the Hetonai series.

It suggests the same provenance that the similar mode of occurrenc of the epidote-augite suite from the Upper Cretaceous formations both in Central and in Southeastern Hokkaido. This suite is probably derived from the axial part of the Hidaka 'zone which begins to turn into a geanticline. Serpentinite masses, distributed now in the Kamuikotan metamorphic zone, peep out in the Uppermost Cretaceous age.

The granite-origin suite in Central Hokkaido is likely derived from a western land. Microcline and perthite grains are often found in the Upper Cretaceous sandstones, though there is no microcline-perthite-bearing granite in the Hidaka

Table 3. Heavy Mineral Assemblages of the Hetonai Series.

	(1)	(2)	(3)	(4)	(5)	(6)
Biotite	2	11	1	4	14	15
Chlorite	5	3	tr	2	14	4
Muscovite				3		1
Ores	28	25	23	22	7	24
Others	65	61	76	69	65	56
	100	**100**	**100**	**100**	**100**	**100**
Other Constituents						
Allanite	1		1	tr		1
Anatase	tr	4	tr			
Augite	2				tr	5
Chromite	11	3	13	8		
Epidote	8				69	61
Garnet (colorless)	5	12	8	6		5
Garnet (colored)	2	1	1	5		
Hornblende (green)			tr			
Hornblende[1]					10	13
Hornblende (brown)	1					
Hypersthene	tr			1		1
Rutile	2	1	2	1		
Sphene	6		2	4		3
Tourmaline[2]	3	4	1	5		1
Tourmaline (green)	1	1	1	1		
Tourmaline (blue)	tr					
Tourmaline (brown)	1	3	tr	tr		
Zircon (colorless)	54	66	71	65	21	9
Zircon (pink)			tr			
Zircon (brown)		tr				
Zircon (purple)	1		tr	1		
Zircon (rounded)	tr	4	tr	3		1
Zoisite	1					
Hematite	12					
Opaques	17	24			1	10
Pyrite	15	33			85	
Authigenic TiO_2	3	11				
Others	53	32			14	90
	100	**100**			**100**	**100**
Heavy mineral index	0.60	0.15	0.14	0.26	0.05	0.76

(1) Bibai, (2) Sunagawa, (3) Utashinai, (4) Ashibetsu,
(5) Nuibetsu, (6) Harutori
1. brownish green, 2. green-purple

Mountains. The granite terrain is not so distant, according to the mode of occurrence of the mineral grains. Zircon is of euhedral crystals with acute bipyramidal terminals; garnet as well as tourmaline grains are angular or sometimes euhedral. It is possible to look for the provenance in the granite masses distributed in the Southwestern "Green-tuff" region.

Purple zircon grains are not recognized in the Kushiro coal field during the Upper Cretaceous and Tertiary periods. If the older sedimentary rocks in the Hidaka zone contained them, it would supply the eastern basin with them. There-

Table 4. Heavy Mineral Assemblages of the Lower Ishikari Group.

	(1)	(2)	(3)	(4)	(5)
Biotite	4	2	5	3	2
Chlorite	1	1	2	1	tr
Muscovite	tr	1	tr	1	
Ores	6	10	7	16	26
Others	89	86	86	79	72
	100	**100**	**100**	**100**	**100**
Other Constituents					
Allanite	1		tr	1	
Anatase	1	2	1	1	1
Augite	1	1	tr	1	1
Brookite	tr	1	tr	tr	tr
Chromite	1	1	1	10	60
Epidote			tr		
Garnet (colorless)	11	11	14	9	10
Garnet (colored)	3	2	2	1	1
Glaucophane				1	
Hornblende[1]	1	1	1	1	1
Hornblende (brown)	1		tr	1	
Hypersthene	1	1	1	1	1
Rutile	2	3	4	2	2
Sphene	4	2	5	5	1
Tourmaline[2]	7	4	6	6	4
Tourmaline (green)	1	2	1	3	2
Tourmaline (blue)	1	1	1		
Tourmaline (brown)	1	1	2	1	1
Zircon (colorless)	61	61	57	54	13
Zircon (pink)	1	1	1	1	
Zircon (brown)	tr	2	tr	tr	
Zircon (purple)	2	2	2	1	1
Hematite	1				
Opaques	30				24
Pyrite	tr	tr	tr	tr	
Authigenic TiO_2	5				13
Others	64				73
	100				**100**
Heavy mineral index	0.06	0.17	0.03	0.06	0.55

(1) Bibai, (2) Naie-Sunagawa, (3) Akabira, (4) Ashibetsu, (5) Yubari

1. brownish green, 2. green-purple

fore, the greater part of the reworked suites would be derived from the west land.

An andesite-origin suite is predominant in the southeastern basin. It is undoubtedly derived from the Shikotan Islands where andesite lava and pyroclastic rocks are found in the Upper Cretaceous formations.

The Upper Cretaceous palaeogeography in Hokkaido is characteristic in emergence of the west and east depositional basins. It means the differentiation of the Yezo geosyncline by gentle upheaval of the axial part. As a matter of

Table 5. Heavy Mineral Assemblages of the Middle Ishikari Group.

	(1)	(2)	(3)	(4)	(5)	(6)
Biotite	3	2	2	2	6	1
Chlorite	1	1	3	5	1	tr
Muscovite	tr	tr	2	tr		
Ores	39	11	13	15	20	20
Others	57	86	82	76	73	79
	100	**100**	**100**	**100**	**100**	**100**
Other Constituents						
Allanite		tr		tr	tr	
Anatase	1	1	tr	tr		3
Augite		2	tr	1		8
Brookite		tr	1	tr	tr	
Chromite	18	2	2	9	13	21
Epidote	tr	tr		tr		
Garnet (colorless)	17	16	15	8	8	4
Garnet (colored)	1	1	2	1	1	tr
Hornblende[1]	tr	tr	tr	tr		1
Hornblende (brown)	tr	tr	tr	tr		1
Hypersthene		2	tr	3		5
Rutile	1	2	2	3	4	17
Sphene	2	4	2	4	3	tr
Topaz			tr			
Tourmaline[2]	2	6	5	10	16	12
Tourmaline (green)	2	2	1	3	9	3
Tourmaline (blue)		1	tr	tr		
Tourmaline (brown)	1	3	1	1	1	1
Zircon (colorless)	50	53	61	51	40	19
Zircon (pink)	1	1	1	1	tr	
Zircon (brown)		tr	1	tr	tr	tr
Zircon (purple)	tr	2	3	1	1	tr
Zircon (rounded)	3	2	2	3	2	5
Hematite		tr				
Opaques	25	43				15
Pyrite	12	10	a	a	a	52
Authigenic TiO_2		5				2
Others	63	42				31
	100	**100**				**100**
Heavy mineral index	0.09	0.06	0.13	0.05	0.11	0.21

(1) Uryu, (2) Bibai, (3) Naie-Sunagawa, (4) Akabira,
(5) Ashibetsu, (6) Yubari

1. brownish green, 2. green-purple

course, the heavy mineral associations reflect the movement, that is, the detrital suites are predominant in the west, whereas the pyroclastic in the east.

2. Ishikari and Poronai age (Eocene-Oligocene)

The Palaeogene formations in Hokkaido are shown in Table 8. Their heavy mineral assemblages are lited in Table 4–7.

The assemblages of the Ishikari and Poronai groups are not so different from those of the Hakobuchi sandstone. They consist of eight suites:

Table 6. Heavy Mineral Assemblages of the Upper Ishikari Group.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Biotite	9	5	5	3	2	2	5	3	2	1	1	7	6
Chlorite	3	3	4	25	4	7	18	4	1	4	6	5	13
Muscovite	tr	tr	tr	tr	tr	tr	1	1	tr		1	tr	1
Ores	4	9	10	9	24	12	20	32	40	23	35	13	27
Others	84	83	81	63	70	79	56	60	57	72	57	75	53
	100	100	100	100	100	100	100	100	100	100	100	100	100
Other Constituents													
Actinolite										2	1	1	
Allanite	tr	tr	tr	tr	tr			tr	1	tr	tr	3	2
Anatase	tr	tr	tr	tr	1	1	1	tr	tr	tr	tr	tr	tr
Augite	2	2	1	1	1	1	1	tr	1	2	1	1	1
Barite			tr										
Brookite				tr	1	tr	1				tr	tr	
Chromite	tr	1	1	1	2	4	12	29	4	5	22	tr	3
Clinozoisite												tr	
Corundum						tr							
Diallage										2	3	1	tr
Diopside										7	6	1	tr
Epidote			?		tr	tr	tr		8	35	20	18	40
Garnet (colorless)	12	18	9	22	25	18	13	10	32	2	7	9	5
Garnet (colored)	2	3	5	3	2	2	2	1	2	1	tr	2	2
Glaucophane			tr										
Hornblende (green)			tr			tr			tr			tr	
Hornblende (bluish)												2	3
Hornblende[1]	1	1	1	tr	1	tr	1	tr	1	8	7	1	10
Hornblende (brown)	1		tr	tr	tr		tr	tr		3	2	1	1
Hypersthene	1	2	1	1	1	1	1	tr	tr		tr	2	tr
Rutile	1	2	4	2	3	4	6	3	2	1	1	1	1
Sphene	3	6	1	2	2	2	1	2	7	4	4	12	11
Spinel											tr	tr	
Topaz				tr	tr						tr		
Tourmaline[2]	19	15	4	6	4	16	22	10	3	13	5	6	3
Tourmaline (green)	3	2	1	tr	1	2	2	3	1	4	2	1	tr
Tourmaline (blue)	tr	tr	tr	tr	tr	tr	1					tr	
Tourmaline (brown)	4	1	2	3	2	3	2	1	3		1	2	tr
Zircon (colorless)	46	43	60	48	46	37	27	37	26	10	15	32	13
Zircon (pink)	tr	1	1	1	1	2	1	tr	tr		tr	tr	
Zircon (brown)	tr	tr	1	1	1	tr	tr				tr	tr	tr
Zircon (purple)	1	2	2	3	2	1	1	tr	1				
Zircon (rounded)	3	2	4	4	2	5	5	3	6	1	2	3	1
Zoisite					tr						tr	tr	
Hematite			tr			7	1					tr	4
Opaques	66	60	38			48	37		35	17	16	12	21
Pyrite	2	1	8			6	3		30		tr	6	tr
Authigenic TiO_2	3	7	7			11	6		3	2	tr	5	tr
Others	39	32	47			28	53		32	81	84	77	75
	100	100	100			100	100		100	100	100	100	100
Heavy mineral index	0.04	0.05	0.07	0.16	0.08	0.07	0.06	0.51	0.05	1.95	1.26	0.47	0.86

(1) Owada, (2) Kabato, (3) Ishikari Plain, (4) Chashinai, (5) Naie, (6) Utashinai, (7) Akabira, (8) Ashibetsu, (9) Yubari, (10) Kamicharo, (11) Urahoro, (12) Nuibetsu, (13) Harutori

1. brownish green, 2. green-purple

Table 7. Heavy Mineral Assemblages of the Poronai and Ombetsu group.

	(1)	(2)	(3)	(4)	(5)	(6)
Biotite	2	2	2	2	3	tr
Chlorite	1	4	7	3	3	tr
Muscovite	tr					
Ores	45	55	36	70	19	14
Others	52	39	55	25	75	86
	100	**100**	**100**	**100**	**100**	**100**
Other Constituents						
Allanite		tr			1	
Anatase	1	3	2	1	1	
Augite	1	3	29	tr	1	31
Brookite		2	tr	tr	1	
Chromite	42	30	7	18	tr	
Diopside				tr		
Epidote				tr	tr	
Garnet (colorless)	4	5	8	17	8	tr
Garnet (colored)	1	3	1	2	2	
Glaucophane		1				
Hornblende[1]	1	tr	4	1	tr	49
Hornblende (green)			1			
Hornblende (brown)	tr	tr	1	tr		15
Hypersthene		1	12	2	2	
Oxyhornblende						4
Rutile	3	9	3	1	2	
Sphene	4	1	3	10	31	tr
Spinel					tr	
Topaz					tr	
Tourmaline[2]	3	5	4	7	5	
Tourmaline (green)	3	3	3	3	3	
Tourmaline (blue)		1				
Tourmaline (brown)	1	2	2	2		
Zircon (colorless)	34	28	14	30	37	tr
Zircon (pink)	1					
Zircon (brown)				tr		
Zircon (purple)		1	1			
Zircon (rounded)	1	2	5	4	5	tr
Zoisite					tr	
Hematite			1	6	tr	8
Opaques	22	7	28	20	16	9
Pyrite	30	44	66	2	3	tr
Authigenic TiO_2		4	1	tr	1	
Others	48	45	4	72	80	83
	100	**100**	**100**	**100**	**100**	**100**
Heavy mineral index	0.55	0.37	0.34	0.20	0.06	2.14

(1) Rumoi, (2) Ashibetsu, (3) Yubari, (4) Shakubetsu,
(6) Nuibetsu, (6) Nuibetsu formation

1. brownish green, 2. green-purple

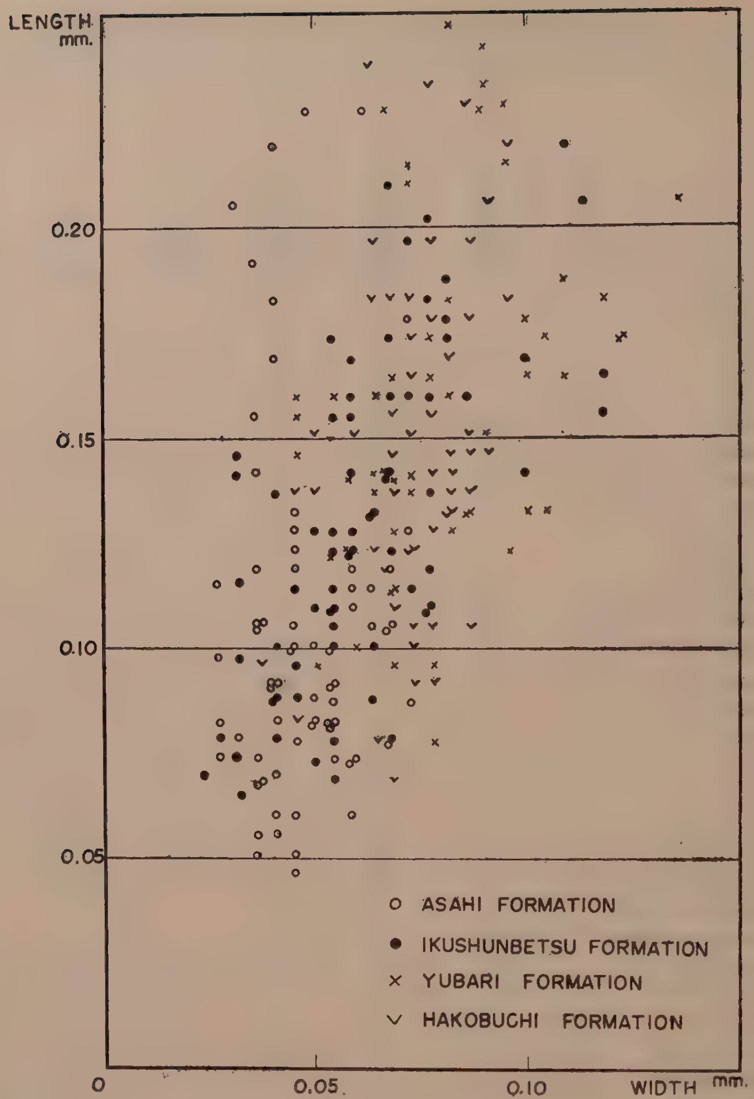


Fig. 11. Length versus width diagram of zircon grains of the Tertiary formations in Central Hokkaido.

i) biotite-garnet-(hornblende)-muscovite-rutile-tourmaline-zircon-ores,
ii) augite-(epidote)-sphene-ores,
iii) chromite-magnetite,
iv) anatase-brookite-zircon,
v) zircon (corroded and sometimes enclosed by glass)-biotite-ores,
vi) hornblende-augite-hypersthene-ores,
vii) rounded grains of zircon, purple zircon, tourmaline, rutile etc.
viii) zircon (overgrowth).

They are originated from granite, diabase and schalstein, ultrabasic rocks, porphyry, liparite, andesite, older sedimentary rocks and contaminated granite, respec- tively. The first suite is predominant through all formations.

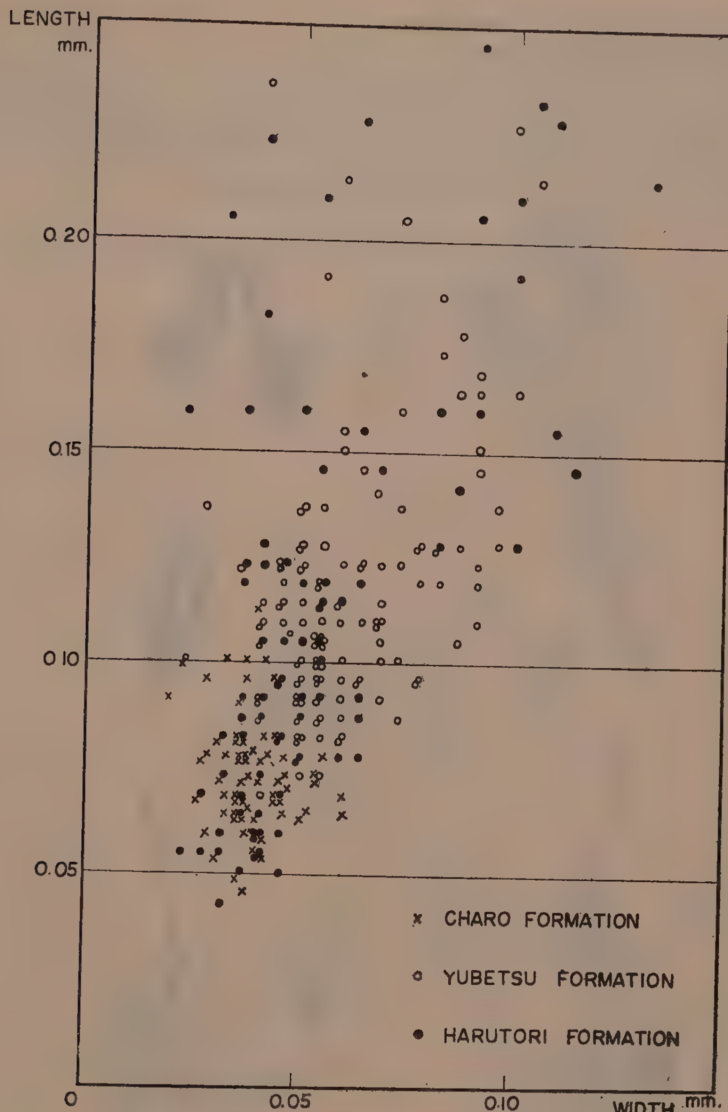


Fig. 12. Length versus width diagram of zircon grains of the Palaeogene formations in the Kushiro coal field.

In the Kushiro coal field, the Palaeogene heavy mineral associations differ from those of the central part. They are composed of ten suites:

i) biotite-garnet-hornblende-rutile-sphene-tourmaline-zircon-ores,
ii) (augite)-epidote-ores,
iii) augite-diopside-hornblende-sphene-spinel-ores,
iv) diallage,
v) chromite-magnetite,
vi) hornblende-hypersthene-augite-ores,
vii) zircon (corroded and sometimes enclosed by glass)-biotite-ores,
viii) zircon (overgrowth),

ix) augite-hornblende-oxyhornblende-ores,
x) rounded grains of zircon etc.

They are derived from granite, diabase and schalstein, gabbro and amphibolite, metamorphosed basic rocks, ultrabasic rocks, andesite, liparite, contaminated granite, basic to intermediate volcanic rocks and older sedimentary rocks. The nineth suite is only found from the Nuibetsu formation.

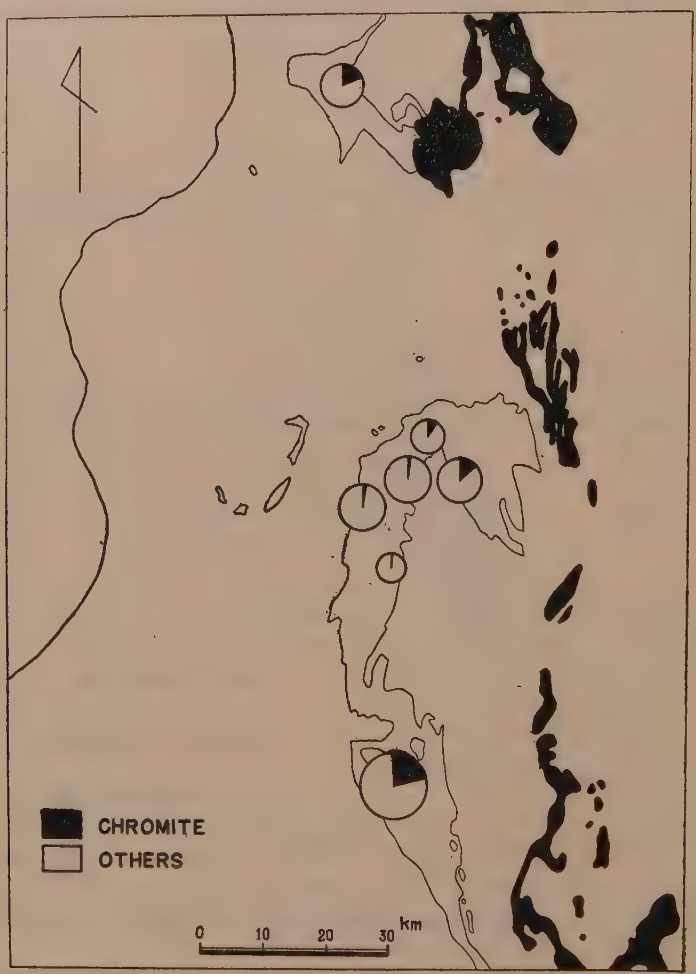


Fig. 13. Heavy mineral index and assemblage of the Middle Ishikari group in Central Hokkaido. Diameter of circle is in proportion to the heavy mineral index. Serpentinite masses are shown by black.

Zircon Problem——Zircon from the Palaeogene formations has several types with different crystal habit, colour and inclusions (see Plate XXII). Some of them are derived clearly from igneous rocks; some are reworked from older sedimentary terrain; and some are originated from contaminated rocks. It now comes into question to correlate the types of zircon to actual igneous bodies. However, it is impossible to resolve the question without studies on

zircon in the provenance.

Euhedral zircon grains are measured the length along *c* axis and the width at right angle thereto. The results are expressed graphically. The elongation ratio (length/width) is mostly 1.5~2.5, but sometimes more than 4.0. Zircon in each formation would have characteristic in shape and size.

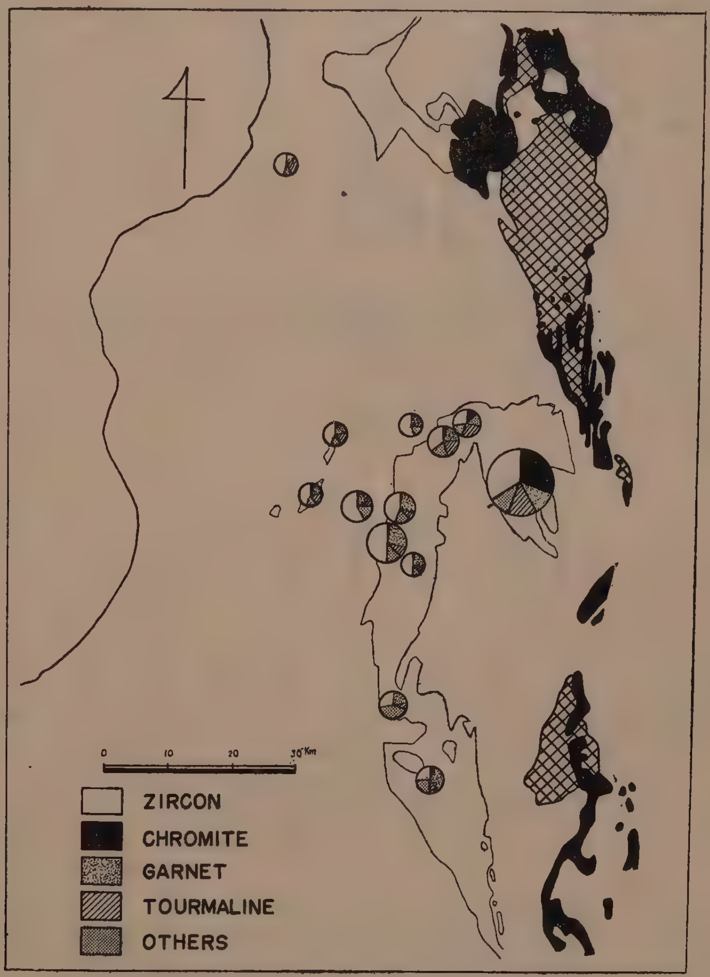


Fig. 14. Heavy mineral index and assemblage of the Upper Ishikari group in Central Hokkaido. Diameter of circle is in proportion to the index.
Kamuikotan metamorphic complex: net
Serpentinite masses: black

Chromite Problem——Chromite occurs with the ultrabasic rock intruding the Kamuikotan zone. It has been present in the Hakobuchi group, but becomes predominant since the Yubari formation. Fig. 10 and 11 express the heavy mineral associations of the lower and middle Ishikari group in Central Hokkaido; the diameter of circle is in proportion to the heavy mineral index. Chromite increases rapidly toward the serpentinite masses of the Kamuikotan zone. This fact clearly indicates the unquestionable provenance of the chromite grains.

Table 8. Correlative Table of the Palaeogene Formations in Hokkaido.

Age	Sequence	Fauna	Flora	Ishikari Coal Field: Yubari	Ishikari Coal Field: East Wing of Sorachi Anticline	Ishikari Coal Field: West Wing of Sorachi Anticline	Rumoi Coal Field	Kabato Mountains: Kabato Coal Field	Kabato Mountains: Owada	Kushiro Coal Field: East Part	Kushiro Coal Field: West Part	Kana-yama Coal Field	Northern Hokkaido
Oligocene	Poronai group	Poronai		Poronai	Poronai		Porookinai				Nuibetsu		
							Tappu				Charo	Pepeshiru	Utsunai
							Shimokine				Omagari Ss.		
	Ishikari group: Upper		Ashibetsu		Ashibetsu	Ashibetsu	Reuke				Shakubetsu		
Eocene					Hiragishi	Hiragishi	Takasago			Shitakara	Shitakara		
										Yubetsu	Yubetsu		
			Woodwardia	Ikushumbetsu	Ikushumbetsu	Ikushumbetsu	Asano	Kabato	Owada	Tenneru	Rushin		
										Harutori			
					Akabira	Akabira	Tachibetsu						
	Ishikari group: Middle		Bibai		Bibai	Bibai	Uryu						
		Wakkanabe		Wakkanabe	Wakkanabe	Wakkanabe	Shiraki						
	Ishikari group: Lower		Yubari	Yubari	Yubari	Yubari							
				Horokabetsu	Horokabetsu	Horokabetsu							
			Noborikawa	Noborikawa	Noborikawa	Noborikawa							
Basement				Up. Cret.	Up. Cret.	Up. Cret.	Up. Cret.	Palaeozoic	Palaeozoic	Up. Cret.	Up. Cret.	Cret.	Cret.

Table 9. Composition of Some Typical Sandstones of the Ishikari Group at Bibai (Mitsubishi) Colliery.

Sample No.	Qz	Ch	Fe	Rf	Ac	Mt
B- 8 (Wk)	8.7%	3.4%	29.5%	1.7%	5.2%	51.5%
B- 133 (〃)	10.2	19.3	11.4	6.2	1.8	51.1
B- 173 (〃)	25.5	30.5	10.0	7.2	—	26.8
B- 609 (Yc)	4.6	3.6	53.8	4.9	0.3	32.8
B- 811 (Hr)	3.0	39.8	19.4	19.5	0.3	18.0
B- 847 (〃)	2.6	16.8	42.7	7.3	2.3	28.3
B- 946 (Nc)	6.2	18.3	36.9	11.0	0.2	27.4
B-1009 (〃)	4.6	33.3	16.8	21.1	0.2	24.0
B-1206 (〃)	18.4	26.5	6.0	28.2	0.8	20.1

Qz: quartz, Ch: chert, Fe: feldspars, Rf: rock fragments, Ac: accessary minerals, Mt: matrix

Table 10. Roundness of Quartz Grains of the Above-mentioned Sandstones.

Sample No.	angular	subangular	subrounded	rounded
B- 8 (Wk)	52%	27%	18%	3%
B- 133 (〃)	52	28	15	5
B- 173 (〃)	44	26	22	8
B- 609 (Yc)	46	36	18	—
B- 811 (Hr)	20	10	40	30
B- 847 (〃)	30	20	30	20
B- 946 (Nc)	15	48	33	4
B-1009 (〃)	33	40	27	—
B-1206 (〃)	52	27	18	3

The Palaeogene age in Hokkaido is divided into four stages based on the standpoint of development of the depositional basins.

(1) Early Ishikari stage (Noborikawa-Yubari)
(2) Middle Ishikari stage (Wakkanabe and Bibai)
(3) Later Ishikari stage (Akabira-Ashibetsu)
(4) Poronai stage

Hokkaido is a continent in the early Palaeogene. A great lake is born in the Early Ishikari stage in the Ishikari coal field area. In the Middle Ishikari stage, the Wakkanabe transgression invades the coal field area from south, extending over as far north as the Rumoi region. Detrital sediments are derived from the surrounding land into the trough during the Early to Middle Ishikari stage. The granite-origin and part of the reworked suites are probably originated from the west continent.[1] The richness of feldspars as well as the angularity of quartz and heavy mineral grains suggest that the granite terrain is not so distant (Table 9, 10).

In the Later Ishikari stage, a transgression occurs in the Kushiro coal field. The sea invades the horse-shoe-shaped basin from southeast to northwest (Fig. 15). The heavy mineral assemblage of the Beppo basal conglomerate is largely represented by the intermediate volcanic rock-origin suite, originated from the Cretaceous volcanic terrain in the Shikotan Islands.

1) Microcline and perthite are still recognized in the sandstones.

The Tenneru formation is composed of conglomerate throughout the whole basin. The center of deposition is situated in the western part of the basin (350 meters thick), and the size of pebbles increases westwards. The gabbroic rock-origin suite is present since the Tenneru age. Its origin is to be looked for in the Hidaka axial zone.

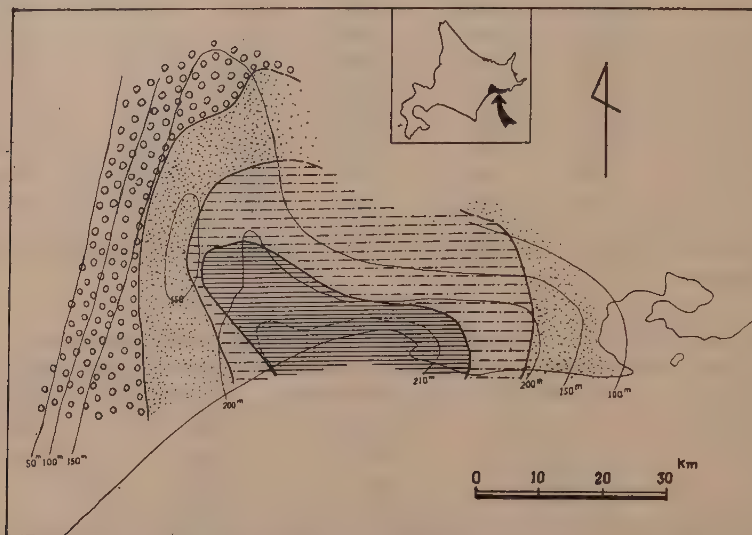


Fig. 15. Isopach and lithological map of the Shitakara formation in the Kushiro coal field.

conglomerate >25%

sandstone >40%

siltstone 40–50%

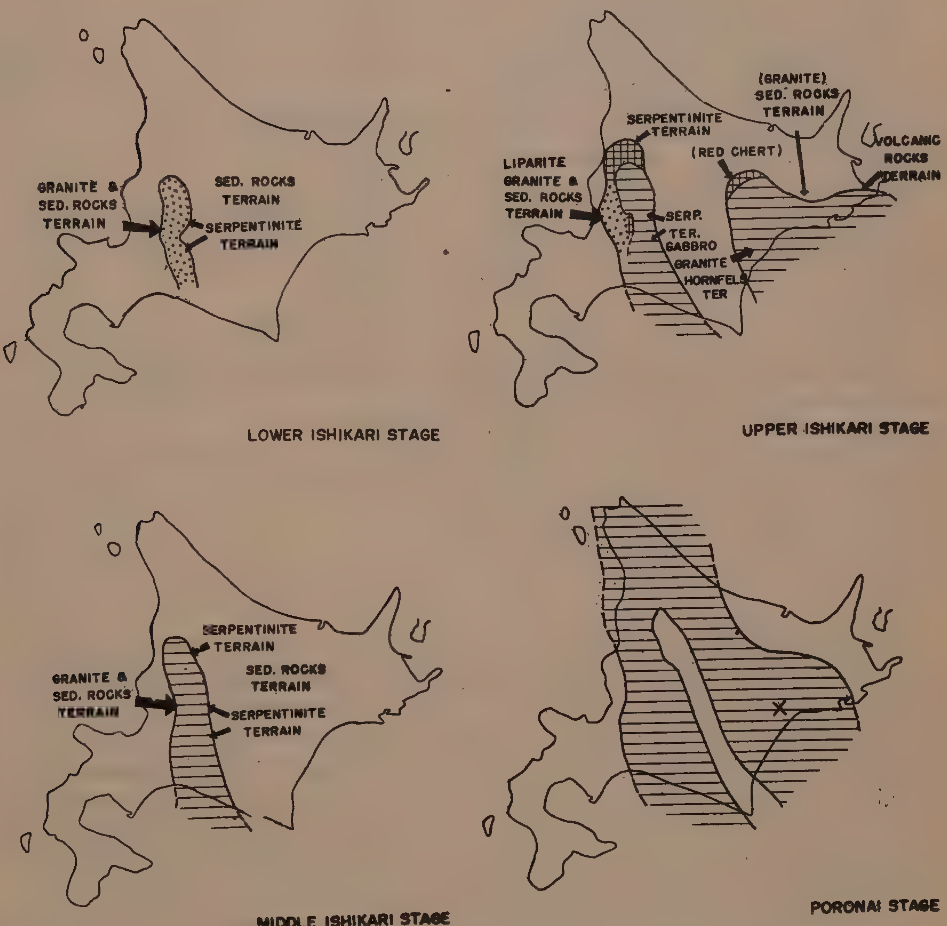
siltstone >50%

Zircon-garnet-tourmaline suite is predominant in the Charo formation as well as in the Harutori, Yubetsu and Shakubetsu coal-bearing formations. The habit of zircon crystals is unchanged throughout these formations. It is interpreted that the grains would be derived from the same provenance. The tendency of decreasing the size of zircon grains upwards may suggest that the granitic intrusive bodies expose their deeper portions as erosion goes on. The granite terrain is also to be sought in the Hidaka axial part.

The Later Ishikari depositional basin, on the other hand, spreads over the Kabato Mountains. A watershed intervening between the Hidaka axial zone and the depositional basin is supposed from absence of the gabbroic suite and occurrence of the ultrabasic suite in the upper part of the Ishikari group. It would be the Kamuikotan zone.

It seems to be striking in the Later Ishikari stage that the opposite things occur at the same time; namely, one is the intense rapid upheaval and succeeding truncation of the Hidaka axial part, and the other enlarging the Palaeogene depositional basins.

A greater part of Hokkaido is covered by sea water during the Poronai stage. Two andesitic volcanic activities are recognized in the Kushiro coal field.



Figs. 16, 17, 18 and 19. Palaeogeographical maps of Hokkaido in the Palaeogene age.
Cross: Center of volcanic activity, Dotted: Fresh water facies, Mesh: Brackish facies, Bar: Marine.

3. Kawabata age (Early-Middle Miocene)

The heavy mineral associations of the Kawabata group are listed in Table 12. They are composed of the following seven suites:

i) biotite-garnet-muscovite-rutile-tourmaline-zircon-ores,
ii) anatase-zircon,
iii) chromite-magnetite,
iv) actinolite-bluish hornblende-epidote-glaucophane-garnet-sphene-ores,
v) hornblende-hypersthene-augite-ores,
vi) augite-brown hornblende-ores,
vii) rounded grains of zircon etc.

They are originated from granite, quartz-porphyry, ultrabasic rocks, the Kamuikotan metamorphic complex, andesite, the Momijiyama formation,[1] and older sedimentary rocks, respectively.

The most characteristic feature in the Kawabata age is that two different troughs are running parallel with each other. One is the newly-formed Miocene "geosynclinal basin" with violent volcanic activity in Western Hokkaido (the so-called "Green-tuff region"); the other the subsiding molasse basin (Kawabata) formed in the front of the Kamuikotan metamorphic zone.

The Asahi and Takinoue formations, the basal part of the Kawabata group, have peculiar heavy mineral associations which are rich in the reworked suites from the Palaeogene and the Momijiyama formations. A characteristic anatase-zircon suite from the Takinoue formation is probably derived from hyperbyssal rocks of the granitic terrain in the Hidaka zone.

Table 11. Heavy Mineral Assemblage of the Momijiyama Formation.

Biotite	
Chlorite	
Muscovite	
Ores	23
Others	77
	100
Other Constituents	
Augite	87
Chromite	tr
Garnet (colorless)	tr
Hornblende (brownish green)	9
Hornblende (brown)	tr
Rutile	1
Zircon (colorless)	1
Zircon (pink)	tr
Zircon (rounded)	tr
Opaques	6
Pyrite	26
Authigenic TiO_2	
Others	68
	100
Heavy mineral index	1.55

The Kamuikotan metamorphic complex-origin suite is commonly found in the middle part of the Kawabata group, namely in the Chikubetsu, Yudoro, Ponsubetsu, and Kawabata formations. The granite-origin suite in the Kawabata formation is derived from the granite terrain in the east. The size and habit of zircon crystals of the suite are very similar to those of biotite-granite pebbles contained in the formation. Furthermore, the granite terrain which has continued to supply detritus during the Upper Cretaceous and Palaeogene age subsides beneath the "Green-tuff geosyncline" in the Kawabata age. Therefore, the granite-origin suite should be derived from the east Hidaka axial part.

The Kawabata formation consists of marine conglomerate, sandstone and siltstone in alternation with graded bedding as well as flow marking. It is typical molasse type sediments, deposited in the front of the Hidaka orogenic zone. Its mineral composition reflects rapid upheaval and succeeding degradation of the orogenic zone. It is strikingly similar to that of the molasse of the Alps.

---

1) The chronology of the Momijiyama formation has been hitherto discussed. Sometimes it was admitted into the Lower Miocene, and sometimes into the Oligocene. Recently, T. TEJIMA addressed an important fact about the stratigraphy of the formation before the Geological Society of Japan at its 65th Annual Meeting held in Sapporo. He reported that the Momijiyama formation overlay the underlying Poronai formation with a remarkable clinounconformity, and that the Takinoue fauna (Middle Miocene) occurred from near the base. It would be possible to correlate the Momijiyama formation to the Fukuyama group (Lower Miocene), because the former has a mixed fauna of the Poronai and the Takinoue elements.

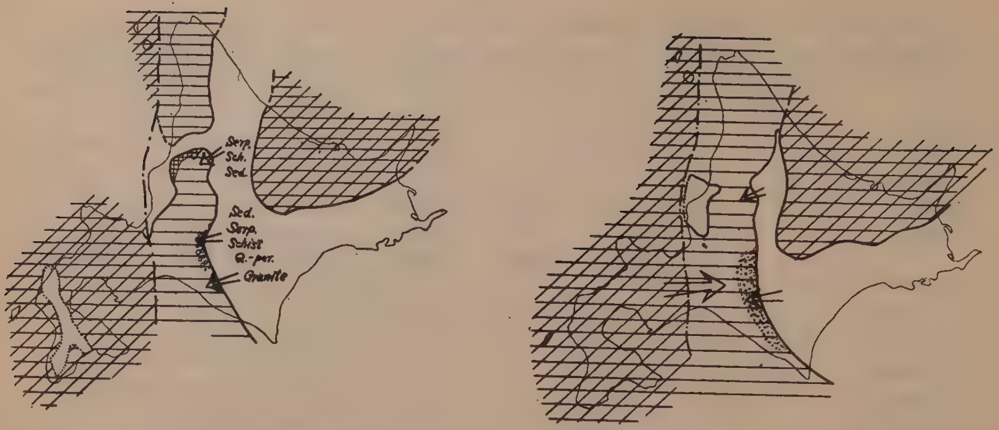
The Momijiyama heavy mineral association is characteristic in predominant andesitic suite which is composed of a large amount of augite and a little brown hornblende. Reworked suites from the underlying Palaeogene formations are also found.

Table 12. Heavy Mineral Assemblages of the Kawabata Group.

	(1)	(2)	(3)	(4)	(5)	(6)
Biotite	1	1	1	2	1	10
Chlorite	2		tr	tr	1	5
Muscovite				tr		1
Ores	73	20	69	56	26	52
Others	24	79	30	42	72	32
	100	100	100	100	100	100
Other Constituents						
Actinolite	2	6	4		tr	1
Allanite	2		1			tr
Anatase		1		5	22	1
Augite		12	4	tr	43	13
Brookite				2		
Chromite	29	3	9	1	12	16
Epidote		33	18			7
Garnet (colorless)	11	1	9	11	4	15
Garnet (colored)	1	2	2	1	1	2
Glaucophane	2	2	2			1
Hornblende (bluish)		12				7
Hornblende[1]		9	2	tr	2	15
Hornblende (brown)		5				2
Hypersthene		6			4	8
Oxyhornblende						
Rutile	1	1	3	4		1
Sphene	6	1	6	1	1	1
Tourmaline[2]	10	1	6	15	2	2
Tourmaline (green)	1		2	5	1	tr
Tourmaline (blue)		1		tr		tr
Tourmaline (brown)	1	1	1	3	1	tr
Zircon (colorless)	29	2	30	45	6	6
Zircon (pink)				1	tr	tr
Zircon (brown)				1		
Zircon (purple)			1	1		
Zircon (rounded)	4	1		4	1	2
Hematite					3	tr
Opaques	3	12	20	22	6	12
Pyrite	21	18	12	1	40	14
Authigenic TiO_2	24			2	tr	tr
Others	52	70	68	75	51	74
	100	100	100	100	100	100
Heavy mineral index	0.32	0.43	0.08	0.60	2.49	1.55

(1) Chikubetsu formation, (2) Yudoro formation, (3) Ponsubetsu formation, (4) Asahi formation, (5) Takinoue formation, (6) Kawabata formation

1. brownish green, 2. green-purple



Figs. 20 and 21. Palaeogeographical maps in Early (left) and Later (right) Kawabata age. "The Green Tuff Regions" are expressed by oblique lines. (Distribuion of marine, brackish and land is after T. HUJIE and others, 1957).

Hornblende-hypersthene-augite-ores suite becomes superior gradually in the upper part of the Kawabata formation. Their possible provenance is the west "Green-tuff region." It is interpreted that the Kawabata molasse basin disappears and is gradually absorbed into "the Green-tuff basin" in the Upper Miocene.

4. Wakkanai age (Upper Miocene)

The heavy mineral assemblages of the Wakkanai group are listed in Table 13.

They are mainly composed of augite-hypersthene-hornblende-oxy-hornblende suite, which is originated from intermediate volcanic activities and andesite terrain.

The Wakkanai transgression spreads over the greater part of Hokkaido. Its deposits have many common features throughout Hokkaido. They consist of a large amount of pyroclastics and hard-cemented siliceous shale, but show an intense lithofacies change.

The Kamuikotan zone successively supplies detritus into the depositional basins.

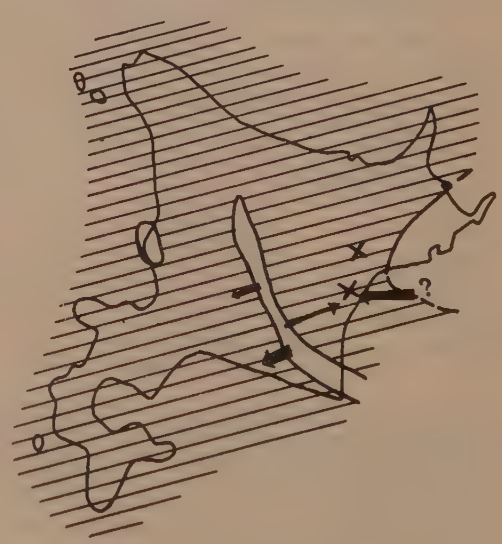


Fig. 22. Palaeogeographical map in Wakkanai age. Centers of volcanic activities in the Kushiro coal field are marked in X. (Distribution of marine and land is after T. HUJIE and others, 1957.)

5. Takikawa age (Lower Pliocene)

The heavy mineral associations of the Takikawa group are shown in Table 14. And they consist of augite-hypersthene-hornblende-ores suite.

Table 13. Heavy Mineral Assemblages of the Wakkanai Group.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aiotite	1	1		1	4		4
Chlorite		tr		1			
Ores	73	3	6	20	20	84	6
Others	26	96	94	78	76	16	90
	100	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents							
Anatase	7			tr	tr		
Augite	7	47	30	6	51	4	39
Chromite	7			3			
Epidote				8	tr		1
Garnent (colorless)	2			1	1		tr
Garnent (colored)	2						
Glaucophane	2			4			
Hornblende (green)		tr		3			
Hornblende (bluish)		6		20			
Hornblende[1]		17	8	40	26	79	24
Hornblende (brown)	4	24	8	8	4	4	12
Hypersthene			54	3	17		22
Oxyhornblende		6		2	1		1
Rutile	7			tr			
Sphene				1			
Tourmaline[2]	16						
Tourmaline (brown)	4						
Zircon (colorless)	13			1	tr	8	tr
Zircon (rounded)	29				tr	4	
Opaques			3		3	19	2
Pyrite			1		7	31	
Authigenic TiO_2			1				
Others			95		90	50	98
			100		**100**	**100**	**100**
Heavy mineral index	0.5	10.80	2.57	0.66	13.88	0.38	5.04

(1) Basal part of the Togeshita formation, (2) Togeshita formation, (3) "Oiwake" formation in the Kabato coal field, (4) Oiwake formation, (5) Chokubetsu and Atsunai formations, (6) Basal part of the Chokubetsu formation, (7) Shiranuka formation
1. brownish green, 2. green-purple

Fig. 23. A geological section of the Hidaka orogenic zone (After M. MINATO et al., 1956).

G: Granite. *J*: Jurassic formation
Cr: Cretaceous formation. *Pg*: Palaeogene formation.
N: Neogene formation of Molasse type.
Mi: Migmatite. *Gb*: Gabbro.
M: Kamuikotan metamorphic complex.
Y: Yubari mountains. *H*: Hidaka Mountains.

Table 14. Heavy Mineral Assemblages of the Takikawa Group.

	(1)	(2)	(3)	(4)
Biotite		2	1	
Chlorite		tr		1
Ores	96	4	10	19
Others	4	94	89	80
	100	**100**	**100**	**100**
Other Constituents				
Augite	31	22	8	39
Epidote		2		1
Garnet	8	1		tr
Hornblende (green)			2	
Hornblende (bluish)		6	2	
Hornblende[1]	23	42	74	23
Hornblende (brown)	15	17	tr	2
Hypersthene		4	11	34
Olivine		3		
Oxyhornblende		2	2	
Tourmaline[2]	8			
Zircon (colorless)	15	1	1	tr
Opaques	1		4	9
Pyrite	1			
Others	98		96	91
	100		**100**	**100**

Heavy mineral index	0.74	1.60	0.60	5.04	1.05

(1) "Takikawa" formation in the Kabato coal field, (2) "Takikawa" formation of the Naie drilling, (3) Kiyomappu sandstone, (4) Hombetsu group at Yubetsu Colliery

1. brownish green, 2. green-purple

The Hidaka Orogenic Movement from a Heavy-mineral Point of View

1. The Hidaka mountain range is an orogenic belt of Alpine type. Its formation and destruction have recently been made clear to a certain degree. It was an epoch-making event in the history of study on the Hidaka orogenic zone that the "Geology of the Hidaka Zone, Hokkaido" was published by M. FUNAHASHI and S. HASHIMOTO in 1951. The outline of the orogen was synthetically grasped for the first time in that thesis on the standpoint of igneous activities, metamorphism, ore deposits and tectonic movement. M. MINATO et al. (1956) developed the orogenic theory on the basis of the preceding works and the newly-discovered data. Moreover, they tentatively connected the geotectonics of the Yezo arc with geophysical phenomena, such as gravity anomalies and explosive seismic waves.

2. Hokkaido comprises three folded mountain arcs as follows: the Yezo arc running from north to south in the central part, the Kuril arc running from east to west, and the Honshu arc running from south to north. The principal zone of the Yezo arc formed a geosyncline in the Jurassic, and subsequently became an orogenic zone in the late Cretaceous, and finally it formed a definite mountain range in the Neogene period (M. MINATO et al. *l. c.*).

3. A heavy mineral association contained in each formation could not also be the exceptional thing which is controlled by any geotectonic movements for each age.

Figs. 26 and 27 represent the range charts of heavy mineral species included by the Upper Cretaceous and Tertiary formations in and near the Yezo arc. There is a possibility to a certain degree that each heavy mineral association would be connected with the formation and destruction of the Hidaka orogenic zone.

4. The Jurassic strata are chiefly composed of thick layers of schalstein, sheets or dykes of diabase, and pillow lavas of weakly alkalic nature, accompanied by limestone, slate and chert. These formations are distributed homogeneously in the wide area of the geosyncline. In the succeeding period, the Cretaceous formations filled up the geosyncline. It is estimated that at first they spread widely all over the geosyncline as continuous strata. However, the Upper Cretaceous strata consist of alternation of sandstone and siltstone, intercalating conglomerate beds. These formations represent a notable lithofacies change (M. Minato et al., *l.c.*).

5. The heavy mineral associations of the Upper Cretaceous formations (the Gyliak and Urakawa series) in the Ishikari coal field are characteristic in predominant epidote, zircon and garnet. The associations in the Kushiro coal field are composed of conspicuous epidote, augite, brownish green hornblende and zircon. Of these, the epidote grains have a very similar mode of occurrence with one another. It is estimated that these grains would have the same provenance——perhaps the emerged surface of the occasionally uplifted axial part of the Yezo arc.

This view has been supported by the evidence that the lithofacies as well as the fauna of the Upper Cretaceous formations are different from each other on both sides of the axial zone. Moreover, the heavy mineral assemblages in the Ishikari-Rumoi zone are notable in non-volcanic detrital suites, originated from granitic and sedimentary terrains[1], while those in the Kushiro coal field are distinct in volcanic suite derived from the volcanic terrain in the Nemuro Peninsula and the Shikotan Islands.

During the Cretaceous period a synorogenic igneous activity occurred at the depths of the core, following which the Yezo arc, formed originally as a single geosyncline in the Jurassic period, began to uplift around the central core. The surface of the axial part probably emerged and suffered erosion.

6. The latest Cretaceous period witnessed gentle uplift and suffering of erosion of the Kamuikotan zone as well as the Hidaka axial zone. This view is evidently supported by the fact that chromite grains which occur in the serpentinite masses in the Kamuikotan zone are found in the uppermost part of the Hakobuchi sandstone at Bibai, Sunagawa, Utashinai, and Ashibetsu in the Ishikari coal field. It becomes evident from Fig. 13 and 14 that they are derived

1) Microcline-perthite granite whose pebbles are contained in the Cretaceous formations is not found in the Hidaka zone (K. Hasegawa et al., 1957). The size of pebbles in conglomerates of the Upper Cretaceous strata tends to increase westwards in the Yubari district (K. Otatsume, 1950). Well-rounded purple zircon grains only occur in the Ishikari-Rumoi zone during the Upper Cretaceous to Palaeogene period, whereas none of them is found in the Kushiro coal field.

from the Kamuikotan zone. Those serpentinite masses, now exposed in the central part of Hokkaido, always appear to intrude into the Cretaceous strata. However, there would be a possibility that in the case of mobile material like serpentinite, formerly intruding bodies move repeatedly during the succeeding tectonic movements in such a manner as salt dome intrusion.

The Hakobuchi group chiefly consists of sandstone and conglomerate, intercalating some coal seams with plentiful plant fossils such as *Nilssonia*, *Cladophlebis* etc. It means considerably extensive upheaval of the Yezo arc.

7. It is worthy of notice that there is a close relation between the geographical distribution of the Upper Cretaceous formations and that of the Palaeogene in Hokkaido (Fig. 24). It should be expected that a possibility of the existence of the similar geologic feature during the late Cretaceous to Palaeogene period.

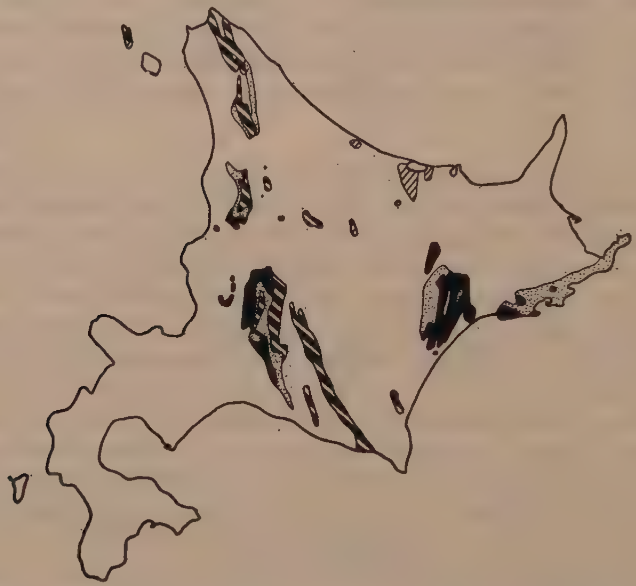


Fig. 24. Distribution of the Cretaceous and Palaeogene Tertiary system in Hokkaido.

Palaeogene formations

Upper Cretaceous formations

Lower Cretaceous formations

Cretaceous formations not to be divided

8. The Palaeogene period in Hokkaido is divided into four stages on the basis of the development of the depositional basin as follows: the Lower Ishikari stage from the Noborikawa formation to the Yubari, the Middle Ishikari stage from the Wakkanabe to the Bibai, the Upper Ishikari stage from the Akabira to the Ashibetsu, and the Poronai stage. The shift of the Palaeogene basin would be equivalent to the pulse of the rising of the Hidaka orogenic zone.

9. The heavy mineral association of the lower Ishikari group inherited the nearly intact character of that of the Hakobuchi group, that is to say, zircon, garnet, tourmaline, rutile, sphene, and chromite are the remarkable constituents. From the point of view of the heavy mineral association, there is a more conspicuous gap between the Urakawa series and the Hetonai rather than the Pre-Tertiary interval. Epidote grains which are a predominant ingredient of the Urakawa series diminish rapidly during the Hetonai age, and become a rare element in the Ishikari group. The Yubari Mountains, of which uplift is represented by apperance of chromite grains during the latest Cretaceous period, would shift the drainage area. Should the fire clay bed at the base of the Ishikari group prove to be originated from a palaeo-soil, the Pre-Tertiary upheaval of the central part of the Yezo arc is probably very gentle.

10. The upper part of the Ishikari group has not the gabbroic suite that will be expressed in the next paragragh. Chromite is only one component that indicates the uplift of the Yubari Mountains. The Kamuikotan metamorphic complex had not or hardly exposed during the Palaeogene period, because its characteristic minerals are very rarely found in the Palaeogene sediments.

11. In the Kushiro coal field, a striking conglomerate formation develops all over the coal basin[1], called the Tenneru or the Rushin formation. It is correlated to the upper part of the Ishikari group, and has a characteristic heavy mineral association, chiefly composed of augite, diallage, diopside, epidote, bluish green hornblende, brownish green hornblende and brown hornblende. The epidote grains are probably derived from the same provenance as that of the late Cretaceous period, being inferred from the mode of occurrence. The other constituents are of plutonic type and are originated from basic rock terrains, such as gabbroic rocks, amphibolite and diallagite. The size of pebbles becomes larger and larger westwards. Generally speaking, the Urahoro group exclusive of the Harutori coal-bearing formation becomes predominant in coarser sediments as going on westwards. J. Ishii (1957) reported the discovery of the gabbroic rock pebbles from the Shitakara formation, of which petrographical character is very

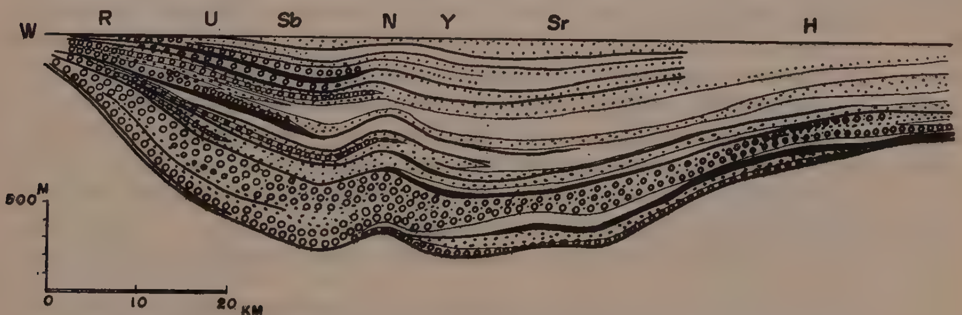


Fig. 25. A geological section across the Kushiro coal basin, from east to west.
H: Harutori Sr: Shoro Y: Yubetsu N: Nuibetsu
Sb: Shakubetsu U: Urahoro R: Rushin

1) Development of the Beppo conglomerate at the base of the Palaeogene formations is limited around the Harutori district. Pebbles differ from those of the Tenneru formation. The heavy mineral association mainly consists of epidote, hornblende and augite inherited from the underlying upper Cretaceous formations.

similar to that of the gabbroic bodies of the Hidaka mountains. M. MINATO et al. (1956) described hornfels pebbles in the Rushin(?) conglomerate. They thought that the hornfels would be derived from the Hidaka central zone.

These facts are enough to support the consideration that the central part of the Yezo arc, uplifted rapidly, suffered erosion to a certain depths, while the Upper Palaeogene formations were deposited around the core.

12. The compositions of some typical sandstones of the Ishikari goup are shown in Table 9. Fragments of older sedimentary rocks are striking with quartz and feldspars grains. Microcline and perthite grains are still found. High angularity of quartz grains suggests a short distant provenance.

13. Considerable degradation of the Yezo arc during the Poronai stage is inferred from the distribution and the lithofacies of the marine sediments. The Oligocene sea, which brought a vast quantity of siltstone of the Poronai-Ombetsu group, would frequently extend to the north part of the Hidaka Mountains, forming a continuous sea[1]. However, occurrence of chromite grains from the Poronai group suggests that the Yubari mountain range would emerge on the sea level. The Ombetsu group becomes sandstone-rich, and at last intercalate conglomerate in the west part of the Kushiro coal field. It also suggests emergence of the Hidaka axial zone on the sea level.

14. Volcanic activities during the Palaeogene period are to be considered from tuffs, volcanic breccia, pyroclastic suites in sandstones[2], and pebbles of volcanic rocks in conglomerates of the Palaeogene strata. Tables 15 and 16 show the Palaeogene volcanic activities in the Ishikari and the Kushiro coal fields.

Although there is no positive evidence that indicates the center of volcanic activity in the Ishikari coal field, it is probably the central part of the Yezo arc where an igneous activity occurred at the depths during the Cretaceous period. It is impossible to find any Palaeogene pyrogenetic strata in the geanticline of Western Hokkaido. The Urahoro group equivalent to the upper part of the Ishikari group intercalates a number of tuffaceous beds, which seem generally to increase their thickness westwards. For example, the tuffaceous bed that is intercalated by the upper coal seams of the Yubetsu formation (12-Shaku or Osappu Seams) develops at the Urahoro and Shakubetsu mines, but diminishes at the Shoro and Harutori mines in the east of the coal field. The Shakubetsu formation has remarkable conglomerate beds that are chiefly composed of white pebbles of trachyte so that called the "Hatokuso" (=doves' droppings) conglomerates; they are only distributed in the west part of the coal field. These facts are estimated that the site of the volcanic activity which brought tuffs and the trachyte pebbles into the coal basin was a land west of the basin. Two andesitic activities during the Poronai stage are recognized at Nuibetsu and Rushin in the

1) H. TAKEDA (1953) studied the Poronai fauna in Hokkaido and Sakhalin and concluded that the fossil contents of the type Poronai area and Eastern Hokkaido are very similar; 42 percents of the species are common to both areas. The lithological similarity with the Poronai of Eastern Hokkaido and that of Sakhalin is also studied. Moreover, the molluscan fossils common to both areas attain 50 percents. These similarities suggested that the formations were deposited in one and the same basin.

2) Sandstones of the Palaeogene strata frequently contain hornblende, hypersthene, and augite crystals of high euhedrality. Moreover, the crystals are often enclosed by volcanic glass. It is considered in safety that they are originated from a volcanic activity.

Table 15. Palaeogene Volcanic Activity in the Ishikari Coal Field.

Formation	Mafic minerals				Opaques		Qtz	Locality
	Biot.	Horn.	Hyper.	Aug.	Mag.	Ilmenite		
Poronai	***	–	*	*	***	–	*	Momijiyama[1]
	*	*	**	***	**	*	–	Numanosawa[2]
	–	*	*	**	**	*	–	Ashibetsu[3]
	–	*	**	***	**	*	–	Yubari[3]
	–	*	**	***	**	*	–	Mayachi[3]
Hiragishi	–	*	*	*	*	*	–	Naie[4]
	–	*	*	*	*	*	–	Do[5].
Ikushumbetsu	***	–	*	–	***	*	*	Wakana[6]
	***	–	–	–	***	*	*	Yayoi[7]
	–	*	*	*	*	*	–	Naie[8]
	–	*	*	**	**	*	–	Chashinai[9]
	–	–	***	**	***	–	–	Wakanabezawa[10]
Akabira	–	**	***	*	**	*	–	Naie[11]
	–	*	**	**	*	–	–	Chashinai[12]
Bibai	–	*	**	*	**	**	–	Bibai[13]
	–	***	*	*	**	*	–	Do.[13]
	–	*	*	–	**	–	*	Do.[13]
	–	**	**	*	***	*	*	Do.[13]
	–	–	***	**	**	*	–	Do.[14]
Wakkanabe	–	*	***	***	**	*	–	Akabira[15]
	–	*	**	***	**	*	–	Mayachi[16]
Yubari	–	*	*	*	**	–	–	Bibai[17]
	*	–	–	–	***	–	*	Yubari[18]
Horokabetsu	–	–	*	*	*	*	–	Sunagawa[19]
	–	*	**	**	*	*	–	Ashibetsu[20]
Noborikawa	–	*	*	*	*	*	–	Sunagawa[21]
Naie Drilling (–655 m.)	–	*	***	**	*	–	–	Naie[22]

1. Tuff of the "H" zone (in the upper part).
2. Sandstone of the "H" zone.
3. Basal glauconitic sandstone.
4. Sandstone in the middle part.
5. The hanging sandstone of the No. 3 coal seam.
6. Woodwardia sandstone.
7. Tuff in the No. 6 coal seam
8. Sandstone in the middle part.
9. Sandstone between the W No. 1 and the W No. 2 coal seams.
10. Tuff in the Toranokawa coal seam.
11. Sandstone in the middle part.
12. Tuff
13. Tuff in the Toranokawa coal seam.
14. Sandstone in the lower part.
15. Sandstone in the upper part.
16. Basal glauconitic sandstone.
17. Tuff in the L No. 4 coal seam.
18. Tuff in the 24–Shaku coal seam.
19. Sandstone in the lower part.
20. The underlying sandstone of the coal seam with tuff.
21. Basal fire clay.
22. Tuff.

Kushiro coal field.

The volcanic activities equivalent to the tuffs in the Ishikari coal field are superior in hornblende-two pyroxene- or two pyroxene-andesite, exclusive of biotite-rhyolite in the Yubari(?), Ikushumbetsu, and Poronai formations. They are probably calc-alkaline rocks.

Table 16. Palaeogene volcanic activity in the Kushiro Coal Field.

Formation	Mafic minerals				Opaques		Qtz	Locality
	Biot.	Horn.	Hyper.	Aug.	Mag.	Ilmenite		
Nuibetsu	–	*	*	**	**	*	–	Nuibetsu[1]
	–	*	*	**	**	*	–	Omagari[1]
Charo	–	*	–	–	**	*	–	Urahoro[2]
	–	**	–	–	**	*	–	Rushin[2]
	–	**	*	?	**	*	–	Do.[2]
	–	*	–	–	**	*	–	Do.[2]
Shakubetsu	–	–	*	*	**	**	–	Atsunai[3]
	–	*	–	–	*	***	–	Shakubetsu[4]
	–	–	–	–	*	***	–	Do.[4]
Yubetsu	***	–	–	–	–	*	*	Shakubetsu[5]
	**	–	–	–	–	**	*	Do.[5]
	**	–	*	–	–	***	*	Chokubetsu[5]
	–	*	***	**	**	*	–	Rushin[6]
Rushin	–	*	***	**	**	*	–	Urahoro[7]
Harutori	–	**	*	*	**	*	–	Harutori[8]

1. Volcanic breccia.
2. Tuff breccia in the lower part.
3. Tuff in the uppermost micaceous coal seam.
4. Trachytic andesite pebble of the Hatokuso conglomerate.
5. Tuff in the 12-Shaku Coal Seam.
6. Tuff in the basal coal seam.
7. Tuff in the upper part.
8. Tuff in the Harutori Coal Seam Proper.

It is worthy of notice that trachyte is found in the Kushiro coal field during the upper Palaeogene period[1].

It might be able to interpret the difference of the nature of the Palaeogene volcanic activities between the Ishikari coal field and the Kushiro with reference to that of the depths of the depositional basins, geological structure, etc. in those areas. M. MINATO et al. (*l.c.*) considered the Palaeogene volcanic activities as the synorogenic volcanic activities of the Hidaka orogenic movement. The writer agrees with their opinion only in the Ishikari coal field. Significance of volcanic activity in the Kushiro coal field will be stated in the succeeding work.

15. At the beginning of the Miocene age, a basic to intermediate volcanic activity accompanied with a little alkaline rock occurred at the Yubari district in the Ishikari coal field. Augite-hornblende-suite is remarkable in the Momijiyama formation.

16. During the succeeding Lower to Middle Miocene age, a long narrow belt of subsiding basin in which a "Molasse" type sediment of the Kawabata group was deposited was formed along the western margin of the Hidaka orogenic zone, while a "geosynclinal" basin with violent volcanic activity (the "Green-tuff" region) was born in western Hokkaido.

The heavy mineral assemblage of the basal part of the Kawabata group, for instance, that of the Asahi and the Takinoue formations, is distinct in the

1) The above-mentioned tuff of the Yubetsu formation has the mineral assemblage that is characterized by abundant ilmenite grains as opaque minerals. It probably occurs under high temperature conditions.

reworked suites from the underlying Palaeogene or the Momijiyama formation.

A very characteristic association of bluish hornblende, epidote, garnet, glaucophane, and sphene suddenly appeared in great quantities in the middle part of the Kawabata group, that is to say, in the Kawabata formation in the Yubari district, the Ponsubetsu in the Kabato coal field, the Yudoro in the Rumoi coal field, and the Chikubetsu in the Tomamae coal field. It is evident that these detrital mineral grains are originated from the Kamuikotan metamorphic complex. Chromite grains that are also derived from the Kamuikotan zone are always accompanied with them.

Another characteristic suite of zircon, garnet, tourmaline, and biotite occurs in the lower part of the Kawabata formation, which entombs many a boulder of granite. These mineral grains and boulders are certainly derived from the central part of the Hidaka mountain range.

Moreover, a profusion of coarser sediments, transported into the Kawabata sea, formed a thick typical "Molasse" type formation.

These evidences suggest a sudden uplift of the axis of the Yezo arc to form a definite mountain range. The Kamuikotan zone probably thrust up during this time.

17. On the other hand, any Lower to Middle Miocene formations are not found in the Kushiro coal field. The Chokubetsu formation belonging to the Upper Miocene age[1] overlies the underlying Palaeogene formations with weak clino-unconformity. An epeirogenetic regional upheaval with gentle folding is recognized in Eastern Hokkaido during the Lower to Middle Miocene age.

18. A characteristic heavy mineral suite, consisting of augite, hypersthene, hornblende, oxyhornblende, and sometimes euhedral hexagonal plate of biotite, is recognized all over the wide area in Hokkaido during the succeeding Upper Miocene age.

These heavy minerals, contained in the Wakkanai group, are possibly derived from the "Green-tuff" region in Western Hokkaido, where an intense volcanic activity occurred. The pyrogenetic or pyroclastic suite had gradually increased since the underlying upper part of the Kawabata formation. The Middle Miocene Takinoue fauna in the "Molasse" basin differs from the Kunnui fauna in the "Green-tuff" region. The Upper Miocene Wakkanai-Togeshita-Atsunai fauna, on the other hand, is found all over the wide area in Hokkaido (T. Fujie and S. Uozumi, 1957).

It becomes evident from the above-mentioned facts that the distinctive character of the Kawabata "Molasse" basin comes to extinction during the Upper Miocene age.

The Atsunai group in the Kushiro coal field has a augite-hypersthene-hornblende suite, which is originated from the site of volcanic activity near the Shakubetsu Colliery.

The Hidaka Mountain range has continued to supply detritus into the depositional basins around the central core. Glaucophane, chromite, zircon, etc. are found in the Wakkanai group. Boulders and pebbles of granitic, gabbroic, mig-

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1) This formation had been hitherto regarded as the Oligocene deposits. T. Tanai (1957) and the present writer have evidently proved in the geological survey from 1955 to 1958 that the Chokubetsu formation overlay the Palaeogene formations clinounconformably, and yielded the Wakkanai-Togeshita-Atsunai fauna belonging to the Upper Miocene age.

matitic rocks are recognized in the basal conglomerate of the Wakkanai group at Hidaka district.

Table 17. The kinds of the pebbles of the Chokubetsu formation (Upper Miocene) in the Kushiro Coal Field, Hokkaido[1)]

Biotite-granite (Kali-feldspar rich)
Biotite-granite (red orthoclase rich)
Coarse-grained granite (perthite and microcline rich)
Green hornblende-biotite-granite
Leuco-granite (Kali-feldspar rich)
Biotite-granite (Kali-feldspar poor)
Granodiorite
Diorite (mylonitization)
Quartz-porphyry
Diorite-porphyry
Porphyrite
Pyroxene-plagioclase-reddish brown hornblende-quartz-porphyrite
Meta-gabbro
Altered gabbro (amphibolitization)
Mylonitized gneiss (polymetamorphic)
Brown biotite-schist
Chiastolite-phyllite (polymetamorphic)
Sericite-chlorite-quartz-meta-slate (silicification)
Hematite-chlorite-sericite-quartzite
Olivine-augite-andesite
Augite-andesite
Augite-andesite (silicification)
Hypersthene-andesite
Glauconite-biotite-plagioclase-orthoclase-quartz-sandstone
Orthoclase-plagioclase-quartz-rock fragments-sandstone
Andesitic subgraywacke
Black slate
Chert

Conclusion

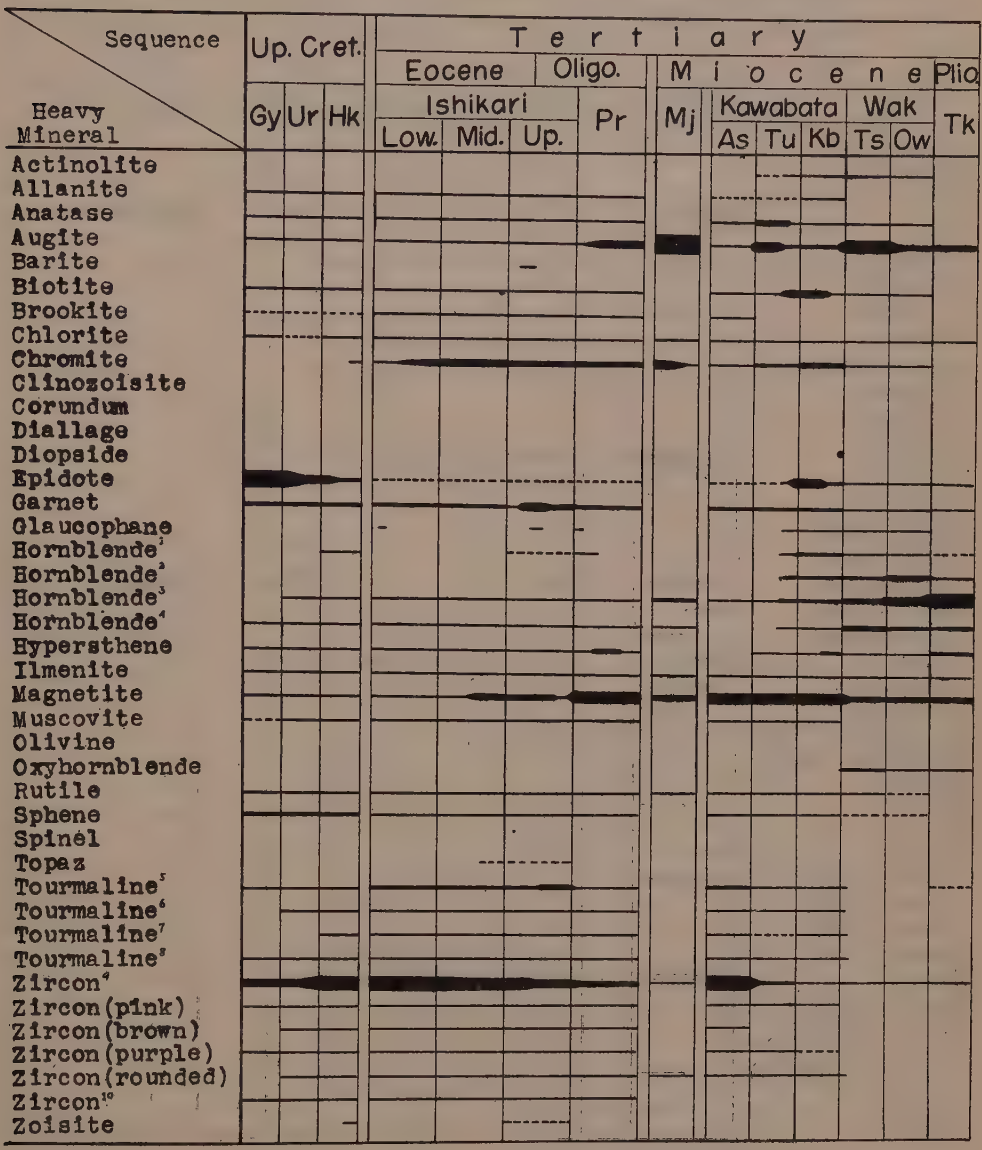
In this thesis, the heavy mineral associations of the Upper Cretaceous and Tertiary formations are firstly studied in Central and Southeastern Hokkaido. Moreover, an outline of geologic history of the Hidaka orogenic zone since the Upper Cretaceous period is tentatively considered from a heavy mineral point of view.

Two range charts of heavy mineral species and a generalized table are finally shown as conclusion.

1) The writer expressed his thanks to Dr. Mitsuo FUNAHASHI in the Geological and Mineralogical Institute of the Hokkaido University for the identification of the thin sections.

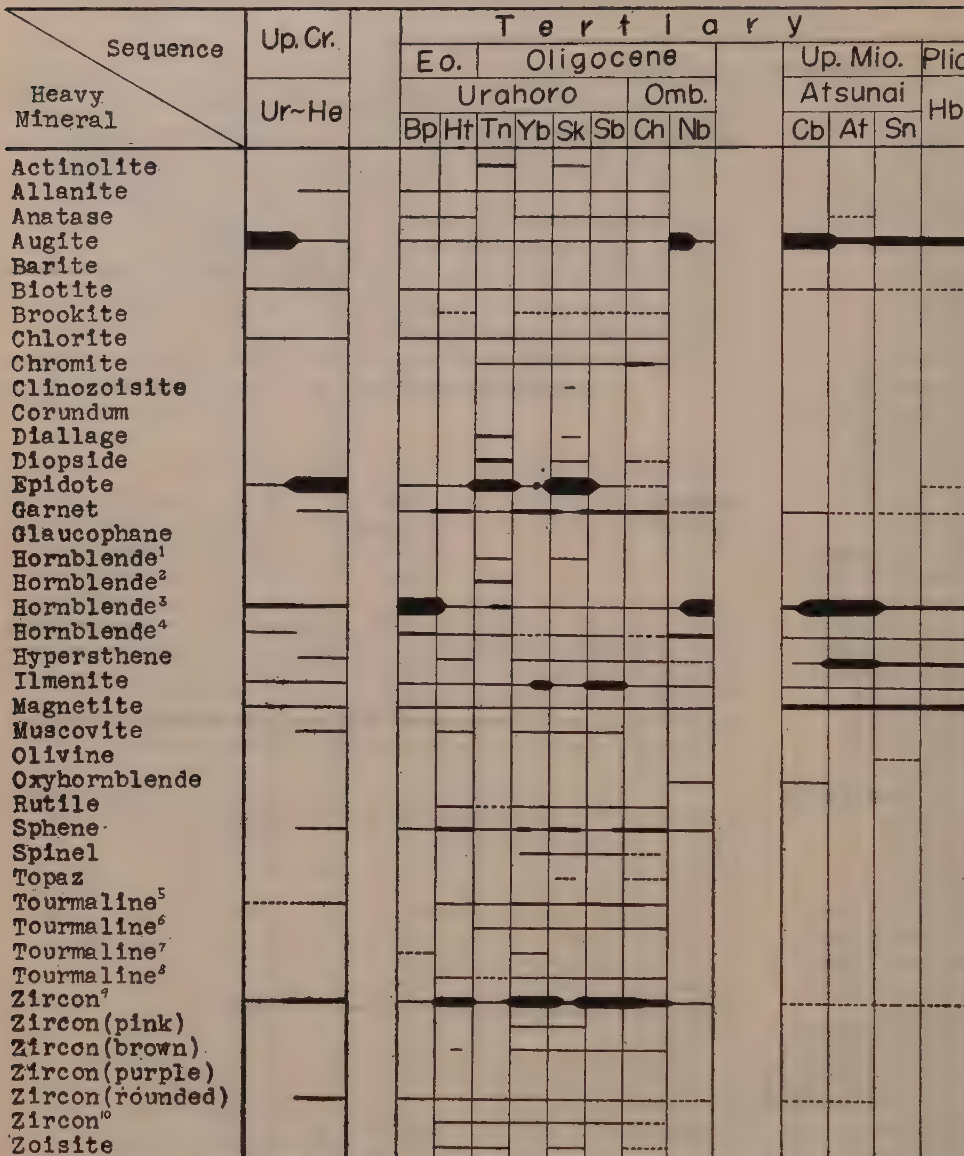
The pebbles of the plutonic and metamorphic rocks of the Chokubetsu formation are not found their provenances in the Hidaka orogenic zone. Orthoclase-perthite rich granite is reported from the Kuril Islands. After M. FUNAHASHI, the biotiteschist and the chiastolite-phyllite are considerably alike to those of the Kitakami Mountains. However, it is doubtful whether the pebbles of the Chokubetsu formation are derived form there. There is a possibility that they are xenolith of the pyroclastic rocks.

Fig. 26. Range Chart of Heavy Mineral Species in the Central Part of Hokkaido.



1. pale green, 2. bluish green, 3. brownish green, 4. brown,
5. green-purple, 6. green, 7. blue, 8. brown,
9. colorless, 10. outgrowth

Fig. 27. Range Chart of Heavy Mineral Species in the Kushiro Coal Field.



1. pale green, 2. bluish green, 3. brownish green, 4. brown, 5. green-purple, 6. green, 7. blue, 8. brown, 9. colorless, 10. outgrowth

Table 18. Relationship among the Heavy Mineral Assemblage,

Age	Sequence		Characteristic Heavy Minerals
Pliocene	Takikawa		Augite, Hypersthene, Hornblende (Chromite, Epidote, Glaucophane, Bluish hornblende)
Miocene	Wakkanai		Augite, Hypersthene, Hornblende, Oxyhornblende (Chromite, Epidote, Glaucophane, Bluish hornblende)
	Kawabata	Upper	Chromite, Epidote, Glaucophane, Garnet, Bluish hornblende, Zircon, Garnet, Tourmaline, Biotite
		Lower	Anatase, Chromite, Reworked minerals derived from the underlying Palaeogene deposits
	Momijiyama		Augite, Hornblende
Oligocene	Poronai		Zircon, Tourmaline, Garnet, Chromite, Hypersthene, Augite, Hornblende
	Ishikari	Upper	Augite, Diallage, Diopside, Epidote, Hornblende, Sphene (in the Kushiro coal field)
Eocene			Garnet, Zircon, Tourmaline, Rutile, Purple zircon, Chromite, Chlorite, Augite, Hypersthene, Hornblende
		Middle	Tourmaline, Zircon, Garnet, Rutile Purple zircon, Chromite, Augite, Hypersthene, Hornblende
		Lower	Zircon, Garnet, Tourmaline, Rutile, Purple zircon, Chromite, Augite, Hypersthene, Hornblende
Late Cret.	Hetonai		Zircon, Garnet, Tourmaline, Rutile, Chromite, Epidote, Purple zircon
			Epidote, Augite, Hornblende, Hypersthene (in Kushiro)
	Urakawa Gyliak		Epidote Zircon Purple zircon Augite, Hypersthene, Hornblende

the Hidaka Mountain Range and the Depositional Basins

<table>
<tr><th>Hidaka Mountains</th><th>Kushiro</th><th>Ishikari</th><th>Green-tuff Region</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Geanticline
Migmatite exposed</td><td colspan="2">Volcanism (basic)
Regional transgression</td><td rowspan="4">Subsiding with violent volcanic activity</td></tr>
<tr><td rowspan="3">Sudden uplift
Kamuikotan metamorphic complex exposed</td><td rowspan="3">Land</td><td>“ Molasse ”</td></tr>
<tr><td></td></tr>
<tr><td>Volcanism (basic)</td></tr>
<tr><td>Degradation</td><td colspan="2">Volcanism (acidic to intermediate)
Regional transgression</td><td rowspan="6">Land</td></tr>
<tr><td>Rapid uplift of the Hidaka central part</td><td>Coal basin</td><td>Deposition in
Ishikari
Rumoi
Kabato</td></tr>
<tr><td rowspan="2">Volcanic activity
(acidic to intermediate)</td><td rowspan="2">Land</td><td>Deposition in
Ishikari
Rumoi</td></tr>
<tr><td>Deposition in
Ishikari
coal field</td></tr>
<tr><td>Upheaval of the Yubari mountains
Serpentinite exposed</td><td></td><td></td></tr>
<tr><td>Synorogenic igneous activity
Uplift of the surface of the axial part</td><td>Volcanism
(acidic to inter mediate)</td><td>Shelf</td></tr>
</table>

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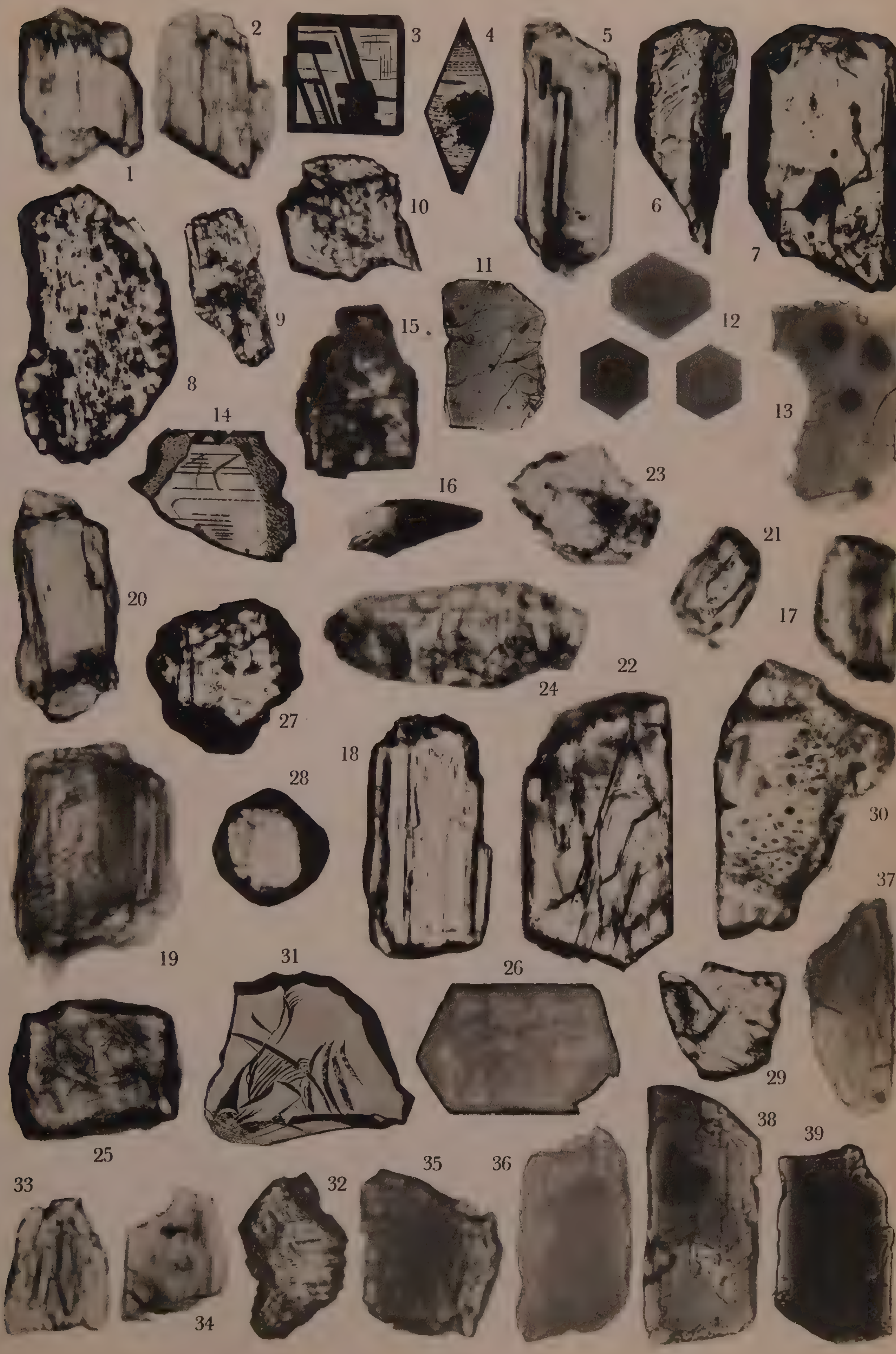
On Relationship Between the Provenances and the Depositional Basins, Considered from the Heavy Mineral Associations of the Upper Cretaceous and Tertiary Formations in Central and Southeastern Hokkaido, Japan

Plate XXI

Explanation of Plate XXI

Fig. 1. Actinolite from the Tenneru formation at Nuibetsu, (AI 520918535) ×173
Fig. 2. Do.
Fig. 3. Anatase from the Ikushumbetsu formation at Akabira, (AI 55081901–05) ×270
Fig. 4. Anatase from the Bibai formation at Naie, (AI 55082508) ×270
Fig. 5. Apatite from the vitritic andesitic tuff of the Harutori formation at the Harutori Colliery, (AI 551103) ×160
Fig. 6. Augite from the andesitic tuff of the Ikushumbetsu formation at Yubari, (AI 581001) ×100
Fig. 7. Do.
Fig. 8. Augite from the andesitic tuff of the Rushin formation at Urahoro, (AI 540906) ×100
Fig. 9. Augite from the Wakkanabe formation at Naie, (AI 55082506) ×90
Fig. 10. Augite from the Harutori formation at the Harutori Colliery, (AI 551103) ×100
Fig. 11. Biotite from the Akabira formation at Akabira, (AI 55081310) ×80
Fig. 12. Biotite from the rhyolitic tuff of the Yubetsu formation at the Shakubetsu Colliery, (AI 540908) ×40
Fig. 13. Biotite from the Yubetsu formation at Nuibetsu, (AI 520917483 (2)) ×80
Fig. 14. Brookite from the Bibai formation at Naie, (AI 55082433) ×200
Fig. 15. Do.
Fig. 16. Chromite from the Yudoro formation at Owada, (AI 53062304) ×200
Fig. 17. Diallage from the Rushin formation at Urahoro, (AI 540928) ×145
Fig. 18. Diallage from the Tenneru formation at Nuibetsu, (AI 520918535) ×145
Fig. 19. Do.
Fig. 20. Diopside from the Tenneru formation at Nuibetsu, (AI 520918535) ×145
Fig. 21. Diopside from the Rushin formation at Urahoro, (AI 540928) ×145
Fig. 22. Diopside from the Tenneru formation at Nuibetsu, (AI 520918535) ×145
Fig. 23. Epidote from the Upper Cretaceous formation at Nuibetsu, (AI 521001) ×145
Fig. 24. Epidote from the Shitakara formation at Nuibetsu, (AI 52090297) ×145
Fig. 25. Epidote from the Tenneru formation at Nuibetsu, (AI 520918535) ×145
Fig. 26. Epidote from the Upper Cretaceous formation at Harutori, (AI 55110201) ×145
Fig. 27. Garnet from the Hiragishi formation at Naie, (AI 55082308) ×145
Fig. 28. Do.
Fig. 29. Do.
Fig. 30. Garnet from the Ikushumbetsu formation at Bibai, (AI 53070529) ×145
Fig. 31. Garnet from the Yubetsu formation at Nuibetsu, (AI 520928(1)LL) ×240
Fig. 32. Garnet from the Hiragishi formation at Akabira, (AI 55082003–04) ×145
Fig. 33. Glaucophane from the Yudoro formation at Owada, (AI 53062304) ×100
Fig. 34. Do.
Fig. 35. Bluish hornblende from the Rushin formation at Urahoro, (AI 540928) ×100
Fig. 36. Bluish hornblende from the Yudoro formation at Owada, (AI 53062304) ×100
Fig. 37. Brown hornblende from the Yudoro formation at Owada, (AI 53062304) ×100
Fig. 38. Brownish green hornblende from the andesitic tuff of the Ikushumbetsu formation at Yubari, (AI 581001) ×100
Fig. 39. Brownish green hornblende from the andesitic tuff of the Bibai formation at Bibai, (AI 53070606) ×100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A. IIJIMA

On Relationship Between the Provenances and the Depositional Basins, Considered from the Heavy Mineral Associations of the Upper Cretaceous and Tertiary Formations in Central and Southeastern Hokkaido, Japan

Plate XXII

Explanation of Plate XXII

Fig. 1. Brownish green hornblende from the andesitic tuff of the Bibai formation at Bibai, (AI 53070606) ×100
Fig. 2. Strongly hackly-etched hypersthene from the Yudoro formation at Owada, (AI 5306230401) ×100
Fig. 3. Hypersthene from the andesitic tuff of the Yubetsu formation at Rushin, (AI 580817) ×100
Fig. 4. Hypersthene from the andesitic tuff of the Rushin formation at Urahoro (AI 540906) ×100
Fig. 5. Hypersthene from the andesitic tuff of the Bibai formation at Bibai, (AI 53070606) ×100
Fig. 6. Hypersthene from the andesitic tuff of the Harutori formation at Harutori Colliery, (AI 551103) ×150
Fig. 7. Muscovite from the Horokabetsu formation at Sunagawa, (AI 550902 S-54) ×120
Fig. 8. Rutile from the Akabira formation at Akabira, (AI 55081902) ×130
Fig. 9. Rutile from the Yubetsu formation at Nuibetsu, (AI 520917483 (2)) ×220
Fig. 10. Do.
Fig. 11. Sphene with hackly-etched structure from the Shitakara formation at Nuibetsu, (AI 520930621) ×220
Fig. 12. Sphene from the Yubetsu formation at Nuibetsu, (AI 520928 (2) LU) ×100
Fig. 13. Sphene from the Harutori formation at Harutori, (AI 55110203) ×120
Fig. 14. Green-purple tourmaline from the Hiragishi formation at Naie, (AI 55082308) ×170
Fig. 15. Green tourmaline from the Yubetsu formation at Nuibetsu, (AI 52091783 (2)) ×133
Fig. 16. Brown tourmaline from the Akabira formation at Akabira, (AI 55081902) ×170
Fig. 17. Green-purple tourmaline from the Yubetsu formation at Nuibetsu, (AI 55082788) ×220
Fig. 18. Zircon from the Noborikawa formation at Sunagawa, (AI 550902 S-57) ×250
Fig. 19. Zircon from the Akabira formation at Akabira, (AI 55081903) ×150
Fig. 20. Zircon from the Ashibetsu formation at Akabira, (AI 55081310) ×200
Fig. 21. Zircon from the Harutori formation at Harutori, (K 6-218) ×220
Fig. 22. Do.
Fig. 23. Zircon from the Noborikawa formation at Sunagawa, (AI 550902 S-57) ×250
Fig. 24. Do. ×170
Fig. 25. Zircon with zonal structure from the Harutori formation at Harutori, (K 6-218) ×100
Fig. 26. Brown zircon with zonal structure from the Noborikawa formation at Sunagawa, (AI 550902 S-57) ×170
Fig. 27. Zircon from the Harutori formation at Harutori, (AI 55110204) ×220
Fig. 28. Zircon from the Yubari formation at Yubari, (AI 57082514) ×140
Fig. 29. Zircon from the Harutori formation at Harutori, (AI 55110204) ×116
Fig. 30. Zircon from the Poronai formation at Ashibetsu, (AI 5703-1) ×180
Fig. 31. Zircon with outgrowth from the Wakkanabe formation at the Naie Colliery, (AI 55082522) ×200
Fig. 32. Zircon from the rhyolitic tuff of the Yubetsu formation at the Shakubetsu Colliery, (AI 540908) ×120
Fig. 33. Zircon from the Poronai formation at Ashibetsu, (AI 5703-1) ×180
Fig. 34. Zircon from the Harutori formation at Harutori, (AI 55110204) ×220
Fig. 35. Zircon from the Noborikawa formation at Sunagawa, (AI 550902 S-57) ×170
Fig. 36. Zircon from the Ikushumbetsu formation at Utashinai, (AI 55082120) ×180
Fig. 37. Purple zircon with zonal structure from the Akabira formation at Akabira, (AI 55081305) ×200
Fig. 38. Purple zircon from the Poronai formation at Ashibetsu, (AI5703-1) ×275
Fig. 39. Purple zircon from the Bibai formation at Naie, (AI 55082411) ×150


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On Relationship Between the Provenances and the Depositional Basins, Considered from the Heavy Mineral Associations of the Upper Cretaceous and Tertiary Formations in Central and Southeastern Hokkaido, Japan

Plate XXIII

Explanation of Plate XXIII

Fig. 1. Sandstone-rich alternation of the Upper Cretaceous formation at Shinkushitakara in the Kushiro coalfield.

Fig. 2. Alternating sandstone, siltstone and marl of the Upper Cretaceous formation of Flysch type sediments at Rushin in the Southwestern Kushiro coalfield.

Fig. 3. Coal-bearing part of the Hakobuchi formation (Uppermost Cretaceous) at the Hakobuchi Gorge in the Ishikari coalfield.

Fig. 4. The Rushin conglomerate formation, the basal part of the Palaeogene Urahoro group, in the southwestern Kushiro coalfield.

Fig. 5. The basal sandstone of the Shitakara formation, the marine facies in the Urahoro group, intercalating Ostrea beds. (Near the Yubetsu Colliery).

Fig. 6. Siltstone with thin tuffaceous sandstone layers of the Nuibetsu formation, the uppermost Palaeogene Ombetsu group at Kamicharo in the Kushiro coalfield.

Fig. 7. Typical graded bedding of the Miocene Kawabata formation of Molasse type sediments at Takinoue near the Ishikari coalfield.

Fig. 8. Alternating thick massive sandstone, thin laminated sandstone and siltstone of the Kawabata formation at Takinoue.

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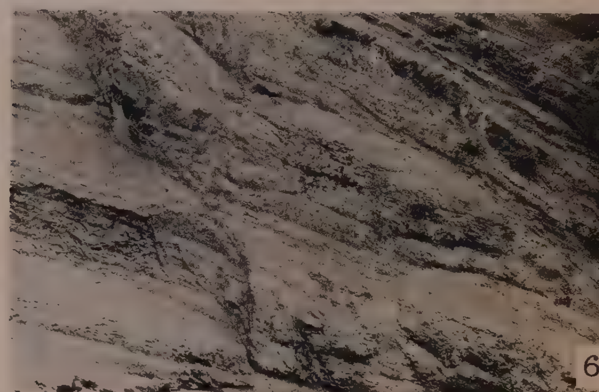

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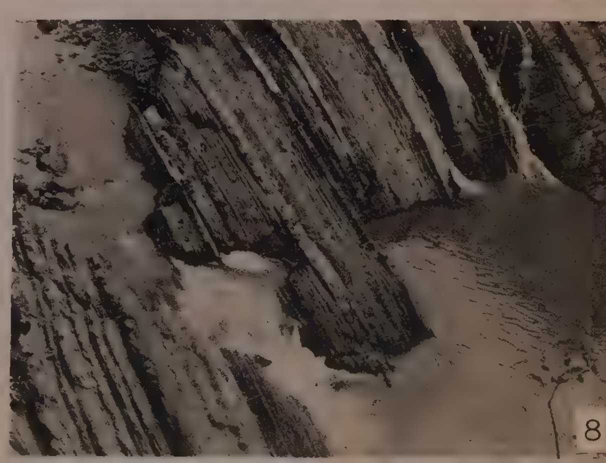

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APPENDIX I

Data on Heavy Mineral Analysis of the Upper Cretaceous and Tertiary Formations in Central Hokkaido

Table 19. Data on Heavy Mineral Analysis of the Cretaceous and the Tertiary Formations in the Uryu District, the Rumoi Coal Field.

Sample No.	53071503	53080802	53061602	53070301	53061902
Biotite	3	4	2	1	1
Chlorite		1	1	1	2
Ores	26	17	61	53	73
Others	71	78	36	45	24
	100	**100**	**100**	**100**	**100**
Other Constituents					
Actinolite					0.7
Allanite					2.1
Anatase	0.8	2.2	0.7	0.4	
Augite				0.4	
Chromite		9.3	26.4	65.2	29.3
Epidote	60.4		0.3		
Garnet (colourless)	6.9	21.1	12.5	2.1	10.7
Garnet (coloured)	2.4	1.0		0.4	1.4
Glaucophane		?			2.1
Hornblende[1]			0.7	1.4	
Hornblende (brown)		0.5		0.4	
Rutile	1.2	1.2	1.4	3.9	1.4
Sphene	2.5	3.2	1.4	2.1	5.7
Tourmaline[2]	0.8	1.5	2.8	1.1	10.0
Tourmaline (green)	0.8	0.5	2.8	1.4	1.4
Tourmaline (blue)	0.4				
Tourmaline (brown)		1.5	1.4	0.4	1.4
Zircon (colourless)	22.0	52.4	46.6	20.4	29.3
Zircon (pink)	0.4	0.7	0.7	0.4	
Zircon (purple)[3]	0.4	0.2			
Zircon (rounded)	0.8	4.4	2.1		4.3
Opaques[4]	24	32	18		3
Pyrite	10	17	6		21
Authigenic TiO_2					24
Others	66	51	76		52
	100	**100**	**100**		**100**
Wt. percentage of heavy residues	0.43	0.04	0.14	0.94	0.32

53071503 Urakawa Series
53080802 Sanke formation, middle Ishikari Group
53061602 Do.
53070301 Shimokine formation, Poronai Group
53061902 Chikubetsu formation, Kawabata Group

1. brownish green, 2. green-purple, 3. well-rounded,
4. limonite and leucoxene.

Ta

Sample No.	53062703
Biotite	
Chlorite	
Muscovite	
Ores	1
Others	99
	100
Other Constituents	
Actinolite	
Allanite	
Anatase	
Augite	100.0
Chromite	
Epidote	
Garnet (colourless)	
Garnet (coloured)	
Glaucophane	
Hornblende[1]	
Hornblende (brown)	
Hypersthene	
Rutile	
Sphene	
Tourmaline[2]	
Tourmaline (green)	
Tourmaline (blue)	
Tourmaline (brown)	
Zircon (colourless)	
Zircon (pink)	
Zircon (brown)	
Zircon (purple)[3]	
Zircon (rounded)	
Hematite	
Opaques	
Pyrite	
Authigenic TiO_2	
Others	
Wt. percentage of heavy residues	10.22

1. brownish green, 2. gre

53062703 Kumanejiri "Palae
River
53062702 Kabato coal-bearing
from the Urausu R
53062810 Kabato coal-bearing
from the Osokinai
53062804 Do.
53062605 Do., collected from
53062504 Kabato coal-bearin
collected from the

le 20. Data on Heavy Mineral Analysis of the Tertiary Formations in the Kabato Coal Field.

53062702	53062810	53062804	53062605	53062504	53062503	53062607	53062606	53062530	53062905	53062608	53071701
8	3	3	12	3	5	5	1	1			4
1	1		10	2	3	6	1	+			1
						1					10
17	16	14	1	3	2	9	13	69	6	96	7
74	80	83	77	91	90	79	85	30	94	4	78
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
								4.2			
	1.2					1.1		1.4			
					0.2						0.8
7.1				3.0	0.5		4.9	4.2	30.7	30.8	0.3
		3.5				1.1		8.6			
								18.2			
17.6	15.5	19.9	5.0	32.0	5.4	25.8	23.5	9.3			4.5
1.8			2.5	2.0	7.2	3.2	4.9	2.1		7.7	
								1.4			
3.5						2.2	2.0	0.7	7.9	23.0	
									7.5	15.4	
1.8				1.0			2.9		53.9		
1.8	1.2		2.5	2.0		4.3	2.0	2.8			1.3
3.5	8.6	9.2	6.2	4.0	4.8	6.5	5.9	6.3			2.9
5.3	7.8	3.5	51.7	11.0	26.5	12.8	2.9	6.3			0.8
3.5	0.4	2.8	5.0		3.0			1.4		7.7	0.8
						1.1					
1.8	0.8	2.1		1.0	1.2	1.1		0.7			3.2
47.4	52.7	43.3	26.0	40.0	50.0	38.9	46.0	31.0		15.4	79.6
1.8	2.9	4.3		1.0	0.6	1.1					1.9
				1.0							
3.5	4.5	7.8		1.0	0.6		1.0	1.4			
	4.5	3.5	1.2	1.0		1.1	3.9				4.0
									3		
59	64	76	54	68	63	57	39	20	1	1	
+	1		2	+		2	4	12	1	1	
15	4	3	9	12	4	7	3				
26	31	21	35	20	33	34	54	68	95	98	
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	
0.03	0.09	0.05	0.04	0.06	0.06	0.02	0.02	0.08	2.57	0.74	0.03

en-purple, 3. well-rounded

ozoic group", collected from the Urausu

formation: basal conglomerate, collected

formation: coal-bearing member, collected
R.

the Tanzan River
formation: upper sandstone member,
Sattekizawa

53062503 Do.
53062607 Do., collected from the Tanzan R.
53062606 Do.
53062530 Ponsubetsu formation, collected from the Sattekizawa
53062905 "Oiwake formation", collected from the Sappinai R.
53062608 "Takikawa formation", collected from the Gogosen R.
53071601 Kabato coal-bearing formation, collected from the Tsukigata Colliery

Table 21. Data on Heavy Mineral Analysis of the Ter

Sample No.	53062203	283	269	258	241	233	222	202	196	187	160	159
Biotite	6	7	10	9	9	24	18	17	21	5	2	6
Chlorite	7	1	1	13	2	12	8			1	11	1
Muscovite		1										
Ores	7	5	4	2	3	6	2	3	7	4	3	3
Others	80	86	85	76	86	58	72	80	72	90	84	90
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents												
Actinolite												
Allanite		0.4				1.5						
Anatase		0.9		1.1						1.1		0.3
Augite	2.4			4.4			12.5	1.8		0.4	0.7	0.7
Chromite		0.4			0.7	1.5				?	2.1	?
Epidote												
Garnet (colourless)	7.7	7.1	10.5	22.0	11.7	16.9	8.3	12.3	15.0	11.2	11.3	7.3
Garnet (coloured)	0.6				0.7	3.1				1.8	2.1	0.7
Glaucophane												
Hornblende[1]												
Hornblende[2]												
Hornblende[3]	1.8			1.1	0.7				5.0			
Hornblende (brown)			2.3	1.1			2.1				0.7	
Hypersthene				1.1								
Oxyhornblende												
Rutile	3.0	1.8		1.1	2.1	4.6	2.1			0.4	1.4	1.4
Sphene	8.3	3.5		3.3	2.5	3.1		10.5		1.8	8.5	2.1
Tourmaline[4]	7.2	14.5	27.9	14.3	9.2	30.8	41.7	33.4	10.0	10.2	5.6	5.2
Tourmaline (green)	0.6	4.0	3.5	4.4	1.1	4.6	10.4	1.8		3.2	2.8	1.0
Tourmaline (blue)					0.4							
Tourmaline (brown)	1.2	4.8	4.7	3.3	2.8	3.1	14.6	5.3	5.0	3.2	2.8	2.8
Zircon (colourless)	59.5	54.5	45.4	41.7	61.0	27.7	8.3	35.1	65.0	57.0	55.7	68.1
Zircon (pink)	0.6	0.4	1.2							1.4	0.7	1.4
Zircon (purple)[5]	0.6	0.9		1.1	0.7					4.2	0.7	2.1
Zircon (rounded)	6.6	6.6	4.7		6.7	3.1				4.2	4.9	6.9
Opaques	58	61	64	59	74	83	80	76	76	59	57	64
Pyrite	2	11	3	2		1		1	1		1	11
Authigenic TiO_2	3	3	6	5	2	1	3	2	5	2	4	2
Others	37	25	27	34	24	15	17	21	18	39	38	23
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.03	0.04	0.04	0.03	0.08	0.04	0.04	0.05	0.02	0.04	0.06	0.0

1. pale green, 2. bluish green, 3. brownish green, 4. green-purple, 5. well-rounded.

53062203 Owada coal-bearing f

283
269
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241
233 Hanging of the Owac
222 Coal Seam Proper,
202 Owada coal-bearing f
196 collected from the Da
187 Nos. represent the de
160
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tiary Formations in the Owada District, the Rumoi Coal Field.

154	142	53062305	53062304	53062303	133	121	109	106	89	90	73	60	50	37	27
5	4	1	1	1	1	5	2								
							1								
7	8	7	18	35	73	1	5	2		1	4		4	6	3
88	88	92	81	64	26	94	92	98	100	99	96	100	96	94	97
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
		0.8	11.7	5.8											
				2.9	6.7										
5.3	0.4	34.1	2.1	1.9	6.7	40.9	23.1	38.5	14.9	95.5	73.2	61.3	61.2	68.8	58.5
			1.9	5.8	6.7										
		21.0	19.1	58.6											
13.2	13.3			1.9	2.2								1.4		
7.9	1.5	0.8	2.1	1.9	2.2										
		2.3	1.1	2.9	2.2										
													0.9		1.0
		10.8	19.1	7.7											
2.6		7.0	23.4			24.2	33.2	24.1	29.4	0.8	9.2	15.5	11.2	11.8	9.6
2.6		3.9	12.7		4.4	26.2	28.0	29.4	45.3	3.4	15.6	21.0	19.4	14.9	27.9
	0.4	17.8													
						8.6	15.6	8.0	10.4	0.4	2.0	2.2	5.9	4.6	3.0
2.6	0.4	1.6	1.1	1.9	6.7										
5.3	1.5														
42.1	10.4		1.9	1.9	15.5										
2.6	1.5														
	1.1			1.0											
2.6	2.2		1.1		4.4										
13.2	59.3		2.1	2.9	13.3										
	3.7														
	4.4			2.9	28.9										
69	46	15	3	17											
	1	2	21	31											
3	5														
28	48	83	76	52											
100	**100**	**100**	**100**	**100**											
0.04	0.02	0.65	0.45	0.20	0.15	5.08	6.58	6.47	3.84	41.89	8.12	18.44	4.12	10.64	2.87

rmation

rmation,
wa No. 1 boring core:
th of the core.

53062305 Marine molluscan-bearing horizon of the Yudoro formation, collected from the outcrops along the Nakayutorimappu-zawa.
53062304 Do.
53062303 Do.

133, 121, 109, 106, 98, 90, 73, 60, 50, 37, 27 — Togeshita formation, collected from the Daiwa No. 1 boring core: Nos. represent the depth of the core.

Table 22. Data on Heavy Mineral Analysis of the Tertiary Formations

Sample No.	N-257	N-238	N-224	N-216	N-178	N-168
Biotite	5	1	1	3	1	3
Chlorite	7	5	2	4	4	1
Muscovite						
Ores	7	5	7	6	13	16
Others	81	89	90	87	82	80
	100	**100**	**100**	**100**	**100**	**100**
Other Constituents						
Allanite	2.3				0.4	
Anatase				0.9	0.8	
Augite		0.5				
Barite						
Chromite		0.5	1.6	0.9	1.3	2.3
Epidote				?		
Garnet (colourless)	6.8	14.2	20.2	11.1	7.9	10.5
Garnet (coloured)	7.9	3.0	5.6	1.3	8.8	7.0
Glaucophane						
Hornblende[1]						
Hornblende[2]						
Hornblende[3]						
Hornblende (brown)			0.4		0.8	
Hypersthene	1.1					
Olivine						
Oxyhornblende						
Rutile	11.5	3.5	6.7	3.1	2.5	1.2
Sphene	1.1	1.0			2.1	1.2
Tourmaline[4]	4.5	2.0	3.6	3.5	3.3	8.7
Tourmaline (green)	2.3	2.0	1.2	0.4	1.7	
Tourmaline (blue)						
Tourmaline (brown)	4.5	2.0	1.2	0.9	2.1	
Zircon (colourless)	52.3	68.6	53.6	72.2	65.8	62.9
Zircon (pink)		0.5	0.4			0.6
Zircon (brown)			0.8	0.9		0.6
Zircon (purple)[5]	3.4	0.5	2.4	1.8	0.4	0.6
Zircon (rounded)	2.3	1.5	2.4	3.1	2.1	4.7
Hematite			+	+	1	+
Opaques	27	37	28	42	29	55
Pyrite	19		2	9	13	7
Authigenic TiO_2	19	21	21	2	1	4
Others	35	42	49	47	56	34
	100	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.08	0.07	0.03	0.13	0.13	0.0

1. pale green, 2. bluish green, 3. brownish green, 4.

Sample No.	Depth (m)	
N-257	629	Coal-bearing formation
N-238	590	Do.
N-224	570	Do.
N-216	554	Do.
N-178	500	Do.
N-168	484	Do.
N-145	459	Do.
N-144	436	Do.

* The samples were kindly offered by the Geological Survey of Japan.

eneath the Ishikari Plain at Naie.*

	N-145	N-134	N-121	N-116	N-107	N-106	N-91	N-81	N-Tk
	10	3	3	3	9	4	1	12	-2
	2	5	1	1	10	17		3	+
					1				
	7	9	18	11	10	9	18	8	4
	71	83	78	85	70	70	81	77	94
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
							0.5		
		0.5	3.7	0.5			0.5	1.0	22.4
						1.4			
	1.2	1.1	0.8	0.9	0.7		0.5	2.0	
									1.6
	10.6	8.5	4.3	4.1	8.7	10.0	5.6	9.0	0.8
	3.0	7.4	3.7	3.6	4.7	5.7	2.0	10.0	
		0.5							
				0.9				2.0	
									6.4
					0.7			2.0	41.6
	1.2		1.4		0.7				16.8
			2.2		2.0		0.5	3.0	4.8
									3.2
									1.6
	3.0	3.7		2.3	6.7	14.3	1.0	4.0	
	1.2	1.6	1.4	0.9	1.3	1.4	0.5	4.0	
	3.6	6.4	1.4	4.6	4.7	8.6	0.5	9.0	
	1.2	2.7	0.8	1.8	1.3		0.5	3.0	
			1.4	0.5				1.0	
	1.2	3.2	0.8	3.6	2.0	1.4		7.0	
	69.3	53.1	71.6	66.4	57.4	45.8	78.4	36.0	0.8
	0.6	1.6							
		2.1		0.9	2.0	1.4	0.5	2.0	
	1.2	3.8	2.9	0.5	1.3	4.3	1.0	1.0	
	3.0	3.8	3.6	8.6	6.0	5.7	8.1	4.0	
		+			+	1			
	48	39	38	36	59	19	26	46	
	2	2	2	1	1	39	8	2	
	3	8	2	8	5	5	2	3	
	47	51	58	55	35	36	64	49	
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	
3	0.04	0.11	0.09	0.08	0.03	0.13	0.13	0.04	1.60

reen-purple, 5. well-rounded.

Sample No.	Depth (m)	
N-121	419	Coal-bearing formation
N-116	400	Do.
N-107	373	Do.
N-106	368	Do.
N- 91	342	Do.
N- 81	328	Do.
N- Tk	241	Takikawa group

Table 23. Data on Heavy Mineral Analysis of the Palaeog

Sample No.	C–1	C–2	C–4	C–6	C–7	C–8	C–10	C–14
Biotite	4		1	1	2	3	6	3
Chlorite	1	1	1		6	21	27	13
Muscovite	1							
Ores	10	5	4	8	18	9	44	7
Others	84	94	94	91	74	67	23	77
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents								
Allanite				0.4	0.5			
Anatase	0.6	0.4	3.2					0.6
Augite		0.4				1.9	9.0	0.3
Brookite								
Chromite	8.0	0.4	0.4	0.7	2.2	2.4		0.3
Epidote								
Garnet (colourless)	9.7	16.9	25.0	11.4	25.3	22.8	28.4	21.6
Garnet (coloured)	0.6	0.4	0.4	1.5	3.2	3.4	1.5	1.5
Hornblende[1]							3.0	
Hornblende (brown)					0.5			
Hypersthene		0.4	1.2			1.5	4.5	0.3
Rutile	3.4	2.9	2.8	1.4	3.2	1.5		3.4
Sphene	2.3	2.1	0.4	0.3	3.2	2.9		3.1
Topaz				1.1		1.0		0.6
Tourmaline[2]	13.6	6.6	13.1	7.7	3.2	5.3	4.5	7.3
Tourmaline (green)	2.3	0.4	0.4					1.2
Tourmaline (blue)	1.1	2.9	3.6	0.4				
Tourmaline (brown)	2.8	2.1	7.5	3.5		2.9	3.0	2.7
Zircon (colourless)	51.2	54.5	35.7	60.2	41.9	43.2	44.7	48.8
Zircon (pink)				1.8		2.4		2.1
Zircon (brown)	1.7	1.2	0.8	2.1		1.0	1.5	0.9
Zircon (purple)[3]	1.7	5.4	3.6	2.5	7.5	2.9		2.7
Zircon (rounded)	1.1	2.9	2.0	5.3	9.2	4.9		2.4
Zoisite			?					
Pyrite	a	a	r	r		a	r	r
Authigenic TiO_2	r				a			
Wt. percentage of heavy residues	0.06	0.07	0.04	0.13	0.32	0.14	0.05	0.07

1. brownish green, 2. green-purple, 3. well-rounde

C–1 Bibai coal-bearing formation
C–2 Do.
C–4 Do.
C–6 Ichinosawa sandstone
C–7 Do.
C–8 Do.
C–10 Ikushumbetsu coal-bearing formation
C–14 Do.
C–16 Do.
C–18 Upper Corbicula (Hiragishi) formation
C–20 Do.

Collected inside the drift (Tsudo) of the Chashinai Colliery.

...e Formations in the Chashinai District, the Ishikari Coal Field.

C-16	C-18	C-20	C-22	C-23	C-24	C-26	C-29	C-32	C-35	C-36	C-36′	C-40
	8	4	4	4	6	3	2	3	4	5	2	2
29	26	20	56	10	19	51	38	30	40	18	24	23
		1							1			
10	8	6	1	7	5	4	7	6	10	6	5	4
61	58	69	39	79	70	42	53	61	45	71	69	71
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
					0.5							
	0.6					0.7	1.1	1.3	0.7	0.9		
	0.6	0.5			0.5	0.7	0.6	0.4	0.7	0.5	0.9	
		0.5		0.4								
2.1	1.9	0.5	0.8	2.0	1.9	0.7	2.2	1.3	2.0	0.9	1.4	1.0
									0.7			
31.9	13.6	26.1	26.2	17.2	16.8	14.7	25.1	18.6	39.1	14.6	16.4	30.2
2.1	0.6	2.5	3.8	2.8	1.0		6.7	3.4	5.3	0.5	2.3	3.9
1.1	1.2					1.5	0.6					
									0.7			
1.1	0.6	1.0	0.8	0.4		0.7	0.6		1.3	0.5	0.5	0.5
3.2	1.2	3.5	3.1	1.5	1.0	1.5	2.2	2.5	2.7	2.3	4.5	6.1
3.2		2.5	1.5	0.8	3.3	1.5	5.6		1.3	1.4	3.2	3.4
	0.6		0.8			0.7	0.6		0.7	0.5	0.9	1.0
	7.4	4.5	6.9	6.3	3.3	11.8	6.7	10.2	4.0	10.9	5.0	9.3
		0.5	1.5	0.4	0.5				0.7	1.8		
		0.5	2.3	0.8	0.5				1.3	0.5		0.5
	1.9	6.0	3.8	3.1	1.4	3.7	4.5	1.2	2.0	11.4		1.6
48.9	59.2	45.3	43.8	54.9	58.8	54.5	36.3	43.3	34.5	50.9	52.3	29.5
	1.9	0.5		2.0	0.5	3.7	2.2	1.7	0.7	0.9	0.5	
	0.6		0.8	1.6		1.5	1.1	0.4		0.9	3.2	2.3
	6.2	2.5	2.3	5.1	3.8	0.7	2.8	3.8	0.7	0.9	6.4	5.0
6.4	1.9	2.5	1.5	0.8	6.2	1.5	1.1	11.8	1.3		2.7	5.3
		0.5										
	a	a	a	r	a	c		r			a	
a			a			r	r	a	c		r	c
0.16	0.46	0.10	0.12	0.07	0.58	0.06	0.09	0.14	0.10	0.08	0.16	0.05

d.

C-22 Upper Corbicula (Hiragishi) formation
C-23 Do.
C-24 Ashibetsu coal-bearing formation
C-26 Do.
C-29 Do.
C-32 Do.
C-35 Do.
C-36 Do.
C-36′ Do.
C-40 Do.

Table 24. Data on Heavy Mineral Analysis of the Upper Cretaceous and Palaeogene Fo

Sample No.	530706Tr	53070614	53070616	53070613	53070617	53070618	53070619	53070620	53070621	53070622
Biotite	5	1	2	2	1	1	11	3	3	2
Chlorite	2	10			1		3	+	1	4
Muscovite						1				
Ores	3	32	24	4	5	4	7	4	7	1
Others	90	57	74	94	93	94	79	93	89	93
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents										
Allanite	1.5		1.3		1.1		1.1			
Anatase		0.5				0.2	0.5	1.1	2.8	0.9
Augite			4.0							
Chromite		14.1	6.9	0.4		0.9	1.3	0.2	1.1	
Epidote			16.3							
Garnet (colourless)	11.8	0.3	9.4	11.2	7.5	10.5	16.7	10.5	13.2	5.7
Garnet (coloured)	3.0	0.5	4.3	3.4	3.2	2.3	6.4	1.6	2.8	2.4
Hornblende[1]				0.4			?		0.8	
Hornblende (brown)	2.2		1.3			0.2		0.5		
Hypersthene	5.9	0.3	0.4	0.8	2.1		0.5			
Rutile	8.9	4.1		0.4	4.3	2.3	1.9	2.1	3.6	3.6
Sphene	14.8	7.3	5.1	3.9	4.3	2.6	7.1	3.9	2.8	2.7
Tourmaline[2]	0.7	2.4	3.4	18.5		1.9	9.6	3.2	11.2	3.6
Tourmaline (green)		0.8				1.2	5.1		1.4	
Tourmaline (blue)		0.5	0.4							
Tourmaline (brown)		0.3			1.1	0.7	2.6	0.7	3.6	0.9
Zircon (colourless)	49.6	67.8	45.1	55.5	68.0	65.8	43.6	68.2	52.8	76.3
Zircon (pink)	0.7					1.6		1.4	0.6	1.2
Zircon (purple)[3]	0.7	1.1		0.4	3.2	4.2	1.9	4.3	1.1	0.9
Zircon (rounded)			0.4	5.1	5.3	5.6	1.9	2.3	2.2	1.8
Zoisite			1.7							
Hematite	6	9	13	2	2	1	2	1	1	1
Opaques	30	20	14	30	26	34	30	14	39	27
Pyrite	4	14	16							
Authigenic TiO_2	2	1	5	6	9	6	1	5	3	5
Others	58	56	52	62	63	59	67	80	57	67
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.06	0.80	0.40	0.04	0.01	0.05	0.04	0.13	0.07	0.10

1. brownish green, 2. green-purple, 3. well-rounded.

530706Tr Trigonia sandstone
53070614 Hakobuchi sandstone
53070616 Do.
53070613 Noborikawa coal-bearing formation, Ishikari Group
53070617 Do.
53070618 Do.
53070619 Do.
53070620 Do.
53070621 Horokabetsu formation
53070622 Do.
53070623 Yubari coal-bearing formation
53070625 Do.

mations in the Bibai District, the Ishikari Coal Field.

53070623	53070625	53070626	53070706	53070606	53070627	53070730	53070602	53070603	53070604	53070607	53070609	53070728	53070729
2	5	3	6	5	1	3	1	2	2	2	2	3	3
	1	+	3		+	1		1	1	1	+	17	1
		+	1	1			+		5			1	1
6	5	12	12	9	5	13	4	15	11	30	10	19	37
2	89	85	78	85	94	83	95	82	81	67	88	60	58
00	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
0.3						0.5							
		0.4	0.9	0.4	0.8	0.7			0.3				1.4
		0.4	0.9		2.3	0.2	3.7	2.7	0.3	7.9	0.2	?	4.2
0.3		0.4	1.7	4.1	1.2	1.0	0.4	0.5	4.1	1.7	0.3	0.3	7.0
										0.9			
5.9	13.9	8.4	7.8	11.1	7.8	14.2	1.0	6.9	10.8	42.0	24.1	24.4	36.6
6.3	2.7	2.3	0.9	0.4	1.4	2.9	0.6	2.1	0.3	2.6	3.8	0.6	12.7
			3.5	0.8					0.3		0.2		
				1.6	1.2						0.3		
0.3		0.6	1.7	0.4	1.4		2.7	5.8	0.3	7.8		0.6	7.0
1.0	2.7	4.1	0.9	2.1	1.4	1.0	3.7	1.6	1.1	1.7	2.1	0.6	4.2
7.3	4.0	4.9	5.2	4.1	7.2	10.8	2.9	3.7	1.1	5.2	1.6	3.0	4.2
2.0	6.0	7.6	12.9	15.8	2.3	5.8	0.2	3.2	4.9	1.7		1.2	4.2
	1.3	1.4	4.3	4.9	1.4	2.4	0.4	2.1	3.2	0.9			
	0.7	0.4			0.4	0.2							
0.3	1.3	1.2		7.0	0.4	2.9	0.2	2.6	2.7	0.9		1.2	
9.8	60.3	59.5	56.9	44.2	64.0	45.5	81.9	63.9	65.7	20.9	63.4	67.2	16.9
1.0	1.3	1.2	2.6	0.4	1.0	1.7	0.2	0.5	2.4				
4.0		2.3		0.4	2.3	5.5	0.6	1.6	0.8	1.7	4.0		
1.6	6.0	4.9		2.1	3.7	4.6	1.4	2.6	1.9	3.5		0.9	1.4
	1	1				1							
7	43	27		51	23	67	30	49	31	40	49	47	43
		+			59	2		1	18	1		8	
1	1	10		2	1	2	5	4	3	21	5	3	22
2	55	62		47	17	28	65	46	48	38	46	42	35
0	**100**	**100**		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
0.04	0.03	0.07	0.03	0.07	0.12	0.08	0.02	0.03	0.02	0.03	0.09	0.03	0.02

53070626 Yubari coal-bearing formation
53070706 Do.
53070606 Wakkanabe formation
53070627 Do.
53070730 Do.
53070602 Bibai coal-bearing formation
53070603 Do.
53070604 Do.
53070607 Do.
53070609 Do.
53070728 Woodwardia sandstone
53070729 Do.
llected from Sannosawa and Takinosawa, the branches of the Bibai River.

Table 25. Data on Heavy Mineral Analysis of the Upper Cretaceous and the

Sample No.	S—1	S—57	S—54	S—44	55082126	55082125	55082122	55082120	55082119
Biotite	11	2	3	2		1	4	1	1
Chlorite	3	+	1	3	2	4	13	8	6
Muscovite		1	1	1					
Ores	25	7	13	8	18	10	21	17	34
Others	61	90	82	86	80	85	62	74	59
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents									
Anatase	4.3	2.3	2.1	3.0	1.3	1.0	0.8	1.7	3.
Augite		0.4	1.1			1.4	?		0
Brookite		1.4	1.1	1.2				0.4	
Chromite	2.7			0.6	10.0			0.4	0
Corundum									
Epidote									
Garnet (colourless)	11.5	11.4	15.3	11.5	8.7	18.9	32.0	34.3	17
Garnet (coloured)	1.1	2.3	2.1	4.9	1.3	2.4	4.0	0.8	1
Hornblende[1]								0.4	
Hornblende[2]					0.4	1.0		0.4	
Hypersthene						0.5			0
Rutile	1.1	5.9	3.2	1.2	5.2	3.3	4.0	3.0	3
Sphene		1.8	1.6	3.6	0.4	1.4	0.8	0.4	1
Tourmaline[3]	3.8	2.7	3.2	9.7	16.6	16.0	19.2	8.1	16
Tourmaline (green)	0.5	1.8	1.6	2.4	3.6	2.4	0.8	2.6	1
Tourmaline (blue)		0.4			0.4	0.5		0.4	
Tourmaline (brown)	2.7	2.7	0.5	0.6	4.4	2.4	1.6	8.1	7
Zircon (colourless)	66.9	52.3	58.9	52.8	41.4	34.3	30.4	27.0	35
Zircon (pink)		0.9			0.4	4.8	0.8	2.6	2
Zircon (brown)	1.1	2.7	1.6	1.8			2.4	1.3	0
Zircon (purple)[4]		4.1	1.1	1.2	0.4	1.0		0.4	1
Zircon (rounded)	4.3	6.8	6.3	5.5	5.7	8.7	3.2	7.7	6
Hematite							1		
Opaques	24				62	73	47	51	54
Pyrite	33							8	2
Authigenic TiO_2	11				7	5	18	5	[illegible]
Others	32				31	22	34	36	2
	100				**100**	**100**	**100**	**100**	**10**
Wt. percentage of heavy residues	0.15	0.15	0.35	0.09	0.06	0.07	0.03	0.04	

1. pale green, 2, brownish green, 3. green-purple, 4. well-rounde

S—1	Hakobuchi Sandstone
S—57	Noborikawa coal-bearing formation
S—54	Horokabetsu formation
S—44	Yubari coal-bearing formation
55082126	Akabira formation
55082125	Do.
55082122	Woodwardia sandstone
55082120	Do.
55082119	Do.
55082118	Do.
55082117	Do.
55082115	Hiragishi formation
55082111	Do.

Tertiary Formations in the Sunagawa-Utashinai District, the Ishikari Coal Field.

	55082118	55082117	55082115	55082111	55082003	55082110	55082005	55082008	53071104	53071106	53071107	53071111
	4	3	1	1	1	8		1	1	4	1	4
	14	13	6	9	3	18	20	5	+	+		
				1						+	+	
	10	13	14	13	10	15		6	5	7	2	12
	72	71	79	76	86	59	80	88	94	89	97	84
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	1.5	0.4	0.8	1.8	1.0	1.0		2.9	0.2			
	1.5		1.6			0.4	9.5					
	0.7		0.8		1.3	0.7		1.6				
			2.3	19.9	1.0	13.9	14.3	1.3	0.8	1.7	1.4	2.0
					1.3							
						0.7						
	22.0	20.3	11.7	7.8	21.5	3.8	9.5	24.5	15.7	25.1	1.9	33.1
	2.2	2.4	3.9	1.2	4.3	0.4		0.6	4.5	0.9		4.0
	0.7				?		4.8					
	0.7	0.8	2.3				4.8			0.4	0.5	
	6.6	4.0	3.1	4.8	3.7	5.6	4.8	3.5	1.7	2.2	1.0	1.2
	2.2	0.8	0.8	0.6	1.7	0.7		0.3	7.4	2.2	5.8	5.2
	22.8	14.2	21.0	19.3	8.1	39.4	33.3	19.1	4.0	6.9	1.4	9.6
	2.9		2.3	1.8	0.3	0.7		1.2	1.3	1.7	1.0	3.6
	0.7					0.7						
	5.9	3.2	0.8	1.2	1.0	1·7	9.5	3.6	0.6	1.3	1.9	
	23.7	36.5	34.4	39.3	42.0	26.1	9.5	30.4	51.2	47.2	83.2	38.2
	3.7	5.7	3.2	0.6	5.4			4.5	1.5	1.7		0.4
		0.4			0.3							
		0.4	0.8	0.6	0.3	0.7		0.6	6.2	6.5		1.2
	2.2	10.9	10.2	1.2	6.7	3.5		5.8	4.9	2.2	1.9	1.6
	3				1	3	84					
	37	35	60	49	31	40	11	67				
	7	11		1		24						
	9	22	19	7	38	4		7				
	44	32	21	43	30	29	5	26				
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**				
07	0.09	0.13	0.14	0.01	0.14	0.01	0.04	0.08	0.07	0.03		0.06

55082003 Hiragishi formation: Lingula-bearing horizon
55082110 Do.: Lingula-bearing horizon
55082005 Do.
55082008 Ashibetsu coal-bearing formation
53071104 Woodwardia sandstone
53071106 Do.
53071107 Do.
53071111 Do.

Series S Collected at the Sunagawa Colliery.
Series 55 Collected from the outcrops along the Utashinai River and from Shakushinaizawa.
Series 53 Collected from the outcrops from Dammanosawa, Takikawa City.

Table 26. Data on Heavy Mineral Analysis of the Palaeogene

Sample No.	4–20	4–22	4–24	1–1	1–2	1–4	1–6	1–7	1–8	55082433	1–11	4–26	1–13	1–14	55082430
Biotite	2	1	4	2	2	3	4	2	2	1	3	4	1	2	2
Chlorite	2	1	1	11	2		5	3	1	1	1	1		2	9
Muscovite														1	
Ores	12	7	4	4	5	9	9	6	10	9	6	14	8	9	4
Others	84	91	91	83	91	88	82	89	87	89	90	71	91	86	85
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents															
Allanite															
Anatase		0.3		1.0	1.6				1.2	0.5	1.3	1.0	0.3		
Augite							1.4		0.3	0.5	0.4				1.5
Brookite	0.7	0.3	0.5	0.3	0.5			0.7	2.1	1.6	1.3	0.5	0.3	1.1	0.5
Chromite	1.9	1.5		2.0	1.1	2.6	1.4	1.7	3.6	3.1	2.2	3.4	0.6	1.4	2.4
Corundum															
Epidote															
Garnet (colourless)	6.6	10.2	12.3	10.9	12.0	14.1	20.0	9.6	9.0	13.6	12.6	13.6	2.9	18.0	18.3
Garnet (coloured)	0.4	1.5	3.8			6.3	0.9	1.7			0.9	0.5		1.1	
Glaucophane							0.5							0.4	0.5
Hornblende[1]	0.4								0.3	1.0				0.4	1.5
Hornblende (brown)					0.5							0.5			0.4
Hypersthene	0.4						1.4			1.0	0.4				0.5
Rutile	0.7	0.6	1.9	2.6	2.2	2.1	3.3	4.6	1.5	4.7	2.2	2.4	1.3	1.4	2.0
Sphene	0.7	1.8	2.8	1.3	0.5	0.5	2.8	2.5	1.8	2.6	0.4	2.9	4.8	2.2	4.4
Topaz		0.3	0.5	0.7				0.7	0.9	1.0		0.5	1.0	0.7	
Tourmaline[2]	2.0	2.8	1.9	3.0	1.1	5.2	15.8	6.3	2.1	6.8	3.6	4.4	1.3	10.5	2.4
Tourmaline (green)	1.6	0.6	1.4	1.0	1.1	2.1		0.7	0.9	3.7	0.9	1.9		2.2	0.5
Tourmaline (blue)												1.5		0.4	
Tourmaline (brown)	1.9	0.9	1.0	1.6	1.1	1.6	2.8	1.7	2.1	1.6	1.3	1.5	0.6	2.5	1.0
Zircon (colourless)	77.0	73.2	65.8	65.7	71.6	56.9	39.3	62.1	67.9	53.4	69.6	55.8	73.6	51.5	54.8
Zircon (pink)	0.4	0.6	1.4	1.0	0.5	2.1	0.5	0.4	0.6	0.5		1.5	3.5	1.1	2.4
Zircon (brown)	1.2	0.9	1.4	1.0	1.6	1.5	1.9	0.7	1.5	1.6	0.9	0.5	0.6	0.4	1.0
Zircon (purple)[3]	2.3	1.2	2.6	4.3	1.6	2.6	6.0	3.3	2.4	1.6	1.3	3.4	5.7	3.2	2.9
Zircon (rounded)	1.9	3.1	2.6	3.6	2.8	2.6	1.9	3.3	1.8	1.0	0.4	4.4	3.5	1.4	2.9
Zoisite															
Pyrite	+	c		a	a	+	r	a		a	r	r	r		a
Authigenic TiO_2	c	c				a	r		r	r		c	r	c	c
Wt. percentage of heavy residues	0.09	0.09	0.13	0.21	0.14	0.12	0.03	0.16	0.06	0.06	0.06	0.09	0.21	0.06	0.0

1. brownish green, 2. green-purple, 3. well-rounded.

4–20 Yubari coal-
4–22 Wakkanabe
4–24 Do.
1– 1 Do.
1– 2 Do.
1– 4 Do.
1– 6 Do.
1– 7 Do.
1– 8 Bibai coal-b
55082433 Do.
1–11 Do.

Series 1: Collected inside the Drift No. 1 of the Naie Colliery,

Series 4: Collected inside the

ormations in the Naie District, the Ishikari Coal Field.

55082660	55082411	55082415	55082651	55082652	55082416	55082418	55082417	55082422	55082423	55082317	55082315	55082314	55082312	55082308	55082301	55082304
2		1	2	3	1	1	3	3		4	1	2	4	3	5	1
4	5	1	9	5	3	5	1	2	1	5	4	7	2	11	2	2
						1										
49	63	61	21	41	61	27	16	14	9	10	27	13	14	17	7	15
45	32	37	68	51	35	66	80	71	90	81	68	78	80	69	86	82
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
															0.8	
								0.7	0.6	1.4		0.4	0.5	2.9	2.0	
0.7			3.8	0.9	1.5		0.5	0.7	0.6	2.0		0.4	1.0	0.6		0.4
		1.1	3.8	1.9	0.6	0.6	0.5	0.4	1.6		0.9		0.5			1.6
1.4	1.7	4.2	1.9	3.7		2.5		1.0	3.2		0.9	2.7	1.5	1.8		
														0.6		
										0.7						
34.8	8.5	17.2	27.0	35.5	45.0	41.2	33.4	19.2	11.9	18.4	21.1	11.3	15.4	20.0	19.7	46.3
7.1	8.5	6.3	8.5		5.4	0.9	0.5		1.7				1.0	5.9	2.4	0.9
			4.8	0.9	1.5	0.6	0.5	0.4		0.7		0.4	0.5		0.4	0.4
			0.9						1.0				1.0			
		2.1	6.6	0.9		0.6		0.7	1.0	1.4	2.6	1.6	1.5	0.6		0.4
4.3		1.1	2.8	3.7	6.2	3.1	3.2	4.5	4.7	0.7	2.6	3.5	5.0	1.2	2.5	2.8
1.4	3.4	4.2	0.9	0.9	2.3	1.6	3.8	1.0	2.6	2.7	1.8	2.0	3.0	1.2	1.6	1.2
0.7					0.6	0.3	0.5		9.4					0.6		0.4
7.0	3.4	2.1	0.9	4.7	1.5	0.9	3.6	2.5		3.4	0.9	5.9	10.0	7.7	8.6	2.2
1.4								3.1		0.7	1.8	0.8	1.0	1.8	2.5	0.4
						0.3			1.1		0.9	0.4				
		1.1	2.8		0.9	2.8	1.6	2.8	1.6	1.4	3.5	3.9	2.5	0.6	4.5	3.4
39.0	67.9	55.3	32.7	44.9	33.2	40.0	48.8	59.1	55.6	59.1	57.8	63.5	51.7	48.6	45.1	36.6
0.7						0.3	0.5	1.0		1.4			1.0	0.6	2.5	
0.7		1.1			0.6	0.3	0.5			2.0		0.8	0.5	0.6	0.8	0.4
0.7	3.4	4.2	0.9	1.9	0.9	0.6	0.5	1.4	1.7	2.0	1.8	1.2	1.5	1.8	4.9	1.2
	3.4		0.9			3.5	1.6	1.4	1.0	2.0	3.5	1.2	1.0	2.9	1.6	1.6
			0.9													
						+	+			a	c	a				+
	a	a	c	a	r	c	r	+	a	a	a		c	a	r	+
0.17	0.42	0.16	0.04	0.02	0.08	0.05	0.04	0.06	0.04	0.14	0.02	0.06	0.06	0.14	0.17	0.05

aring formation
rmation

ring formation

4-26 Bibai coal-bearing formation
1-13 Do.
1-14 Do.
55082430 Do.
55082660 Do.
55082411 Do.
55082415 Akabira formation
55082651 Do.
55082652 Woodwardia sandstone
55082416 Do.
55082418 Do.

55082417 Woonwardia sandstone
55082422 Do.
55082423 Do.
55082317 Do.
55082315 Upper Corbicula (Hiragishi) formation
55082314 Do.
55082312 Do.
55082308 Do.
55082301 Do.
55082304 Ashibetsu coal-bearing formation

ift No. 4 of the Naie Colliery, Others: Collected from the outcrops along the Naie River.

Table 27. Data on Heavy Mineral Analysis of the Upper Cretaceous a

Sample No.	53071001	53071012	53071003	53070904	53070903	53070924	53070922	53070921	53071001	53071003	53071004	53071007	53071006	53071005
Biotite	+	2	8	6	3	5		4	+	1	3	3	2	3
Chlorite		1	7	1		2			3		2	4	9	1
Muscovite				+	+		18				+	1	1	1
Ores	32	14	4	6	10	7		10	46	10	22	18	18	11
Others	68	83	81	87	87	86	82	86	51	89	73	74	70	84
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents														
Allanite	0.8	1.6		0.5	0.3	0.6				0.3		0.5	1.2	
Anatase	0.4	0.3		1.0							0.5			
Augite				0.5					14.5					0.7
Brookite														0.7
Chromite	16.0	8.7		1.0	1.2	0.6		0.6	33.1	3.3	18.7	13.2	14.6	7.9
Epidote					0.3									
Garnet (colourless)	5.4	11.2	38.4	4.9	4.1	9.5	7.1	13.5	2.1	8.5	8.9	6.8	6.1	4.0
Garnet (coloured)	0.8	0.6	4.7	0.5	0.6	2.5			2.8	0.8	1.0			0.7
Hornblende[1]	0.4													
Hornblende[2]					0.3				1.4		0.4			0.7
Hornblende (brown)					0.3				1.4				1.2	
Hypersthene					1.5				16.6					1.3
Rutile	1.3	1.9	2.3	1.5	1.2	12.7		4.5	2.8	2.2	2.9	6.8	4.9	1.3
Sphene	2.9	1.9	5.8	2.4	4.1	7.6	7.1	3.2	1.4	6.8	2.5	4.5	1.2	5.3
Tourmaline[3]	0.4	1.6	3.5	12.3	5.2	3.8		5.1	3.5	5.8	10.8	16.4	24.4	8.0
Tourmaline (green)		1.9	1.2	2.0	1.7	0.6		1.9		2.2	6.9	4.1	2.4	0.7
Tourmaline (blue)					0.9			0.6				0.5		0.7
Tourmaline (brown)		0.3		5.4	2.0	0.6		0.6		1.9		2.7	3.7	1.3
Zircon (colourless)	70.0	69.3	36.1	62.3	69.0	60.2	85.8	64.2	20.0	60.0	43.9	38.2	37.8	58.9
Zircon (pink)	0.8		1.2	2.4	2.3			0.6		0.8		1.4	1.2	1.3
Zircon (brown)														
Zircon (purple)[4]	0.4	0.3	2.3	0.5	2.6	0.6		1.3		2.2	2.0	3.2	1.2	2.0
Zircon (rounded)	0.4	0.3	4.7	2.9	2.6	0.6		3.8	0.7	5.2	1.5	1.8		4.6
Hematite														
Opaques														
Pyrite														
Authigenic TiO_2														
Others														
Wt. percentage of heavy residues	0.09	0.19	0.01	0.02	0.06	0.02	0.16	0.07	0.04	0.10	0.01	0.03	0.02	0.01

1. pale green, 2. brownish green, 3. green-purple, 4. well-rounded.

53071001 Hakobuchi s
53071012 Do.
53071003 Noborikawa
53070904 Yubari coal-
53070903 Do.
53070924 Do.
53070922 Wakkanabe
53070921 Do.
53071001 Do.
53071003 Bibai coal-b
53071004 Do.

nd the Palaeogene Formations in the Akabira District, the Ishikari Coal Field.

53070902	53070920	53070901	530709Bc	55081908	53071009	530709Lc	55081303	55081304	55081902	55081903	55081904	55081305	55081901	55081906	55081309	55081308	55081311	55081310
	2	3	3	3	5		1	4	4	7	8	6	5	5	11	3	5	7
	7	1	2	38			53	21	10	36	35	28	22	5	26	4	6	6
			2	4			1	1	4	1	5		1					
	5	5	19	6	25	27	12	10	14	5	8	5	10	13	30	50	91	53
	86	91	74	49	70	73	33	64	68	51	44	61	62	80	33	43	70	34
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
		0.4	0.9															
	1.0	1.0	1.3	1.7			3.6		2.3	1.0	1.5	1.8	1.0		0.5		0.3	
				1.0			3.6	0.6	0.4	2.0			1.0	1.7		0.5		0.4
				1.0			3.6	0.6	0.4	1.0	0.8	1.3	1.6			0.5	0.3	
.6		0.6	12.0	0.4	21.4	12.5		0.6	2.3	7.2	14.0	2.6	4.7	3.5	18.7	33.6	21.0	25.2
3																0.5		
.5	3.3	3.1	12.4	22.6	7.1	12.5	32.8	14.5	16.2	5.8	10.1	17.1	2.6	6.9	10.9	13.3	20.2	12.7
.7	1.0	1.2	2.2	1.4			3.6	1.9	2.7	3.4		0.4	2.1		3.6	3.8	0.9	6.2
						12.5		0.6				0.4						
		0.2	0.4			12.5		0.6	0.4	1.0			0.5		0.5			
.2	0.5	0.6	2.7	5.5	3.6	12.5	3.6	5.1	2.7	7.7	14.7	4.8	4.7	3.5	6.7	2.4	6.0	1.1
1	5.2	5.9	4.4					0.6	0.6	1.4	1.5	0.4	0.5		2.1	3.3	1.4	0.4
0	16.7	5.3	11.1	9.8	10.7		11.0	35.8	23.9	15.9	33.3	27.6	36.9	53.4	14.0	14.2	13.0	22.2
0	6.2	1.2	4.9		10.7		1.8	2.5	1.8	1.9	0.8	3.1	1.1	3.5	1.6	0.9	1.1	
		0.4	0.4	1.7	3.6			1.3	0.4	1.0	2.3		0.5		2.1		0.3	0.4
	3.3	0.8	2.7	0.7			3.6	4.4	4.1	3.4	3.1	5.7	0.5		0.5	0.9	0.6	0.4
8	56.7	75.9	44.4	33.5	39.3	37.5	23.7	18.2	29.3	29.0	15.6	23.8	33.8	25.8	26.9	19.9	24.8	25.6
3	1.0	0.4		3.5				3.8	1.8	2.9					1.0		0.3	
				1.0				0.6	1.8	0.5			1.1		0.5	0.5		
3	2.9	1.2		0.4	3.6		3.6		0.9	1.4		5.3	1.6	1.7	2.6	0.9	1.4	0.4
.0	2.4	1.8		15.7			5.5	8.3	7.7	13.5	2.3	5.7	5.8		7.8	4.8	8.4	5.0
				1			3	1		1				1				4
				40			24	70	51	51	34	51	42	37	43	32	39	37
				1			1	1	17	2	20	1		1				
							16		6	9	1	1	7	32	2	4	6	6
				58			56	28	26	37	45	47	51	29	55	64	55	53
				100			**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
09	0.03	0.03		0.07	0.01	0.01	0.03	0.09	0.08	0.12	0.07	0.05	0.08	0.02	0.05	0.10	0.09	0.10

ndstone

coal-bearing formation
earing formation

ormation

aring formation

53071007 Bibai coal-bearing formation
53071006 Do.
53071005 Do.
53070902 Do.
53070920 Do.
53070901 Do.
530709Bc Do.
55081908 Do.
53071009 Akabira formation
530709Lc Do.
55081303 Do.

55081304 Akabira formation
55081902 Do.
55081903 Do.
55081904 Do.
55081305 Do.
55081901 Woodwardia sandstone
55081906 Do.
55081309 Hiragishi formation
55081308 Do.
55081311 Ashibetsu coal-bearing formation
55081310 Do.

Table 28. Data on Heavy Mineral Analysis of the Upper Cretaceous and the Tertiary For

Sample No.	53071301	53071302'	53071302	53071304	53071305	53071306	53071307	53071308	53071309	53071310	53071311
Biotite	2	5	5		1	7	2	11	3	+	3
Chlorite	4		2	+	1	3	+	2	2	+	1
Muscovite	10					5		1			
Ores	27	15	25	18	8	5	7	7	6	47	26
Others	57	80	68	82	90	80	91	79	89	53	70
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents											
Allanite						2.2	0.5		0.9	1.2	0
Anatase				0.9	0.5	4.3		1.5	2.8		
Augite									9.4		
Brookite											
Chromite	7.9		7.3	5.7	0.3		1.1			54.1	23
Garnet (colourless)	2.6		9.8	7.7	5.6	6.5	23.1	7.8	12.2	0.6	7.
Garnet (coloured)	2.6		7.3	0.9	0.3		1.9			0.6	0.
Glaucophane								1.0			
Hornblende[1]								0.5	3.7		
Hornblende (brown)				0.2	0.3				1.9		
Hypersthene	2.6								8.4		
Rutile	7.9		2.4	0.4	1.3	2.2	1.4	3.9	3.7	1.2	3
Sphene	5.3			7.8	4.6	4.3	8.4	1.0	4.7	4.3	0
Tourmaline[2]			4.9	0.5	1.6	10.9	1.9	9.7	4.7	6.2	11
Tourmaline (green)			2.4		1.3	10.9	0.8	5.8	1.9	1.2	
Tourmaline (blue)											1.
Tourmaline (brown)					0.3		0.3	1.9	0.9	0.6	0.
Zircon (colourless)	68.4		61.0	68.8	80.6	56.5	54.4	63.6	39.3	28.0	46
Zircon (pink)				1.1	0.3		0.8	1.5	1.9		
Zircon (purple)[3]			2.4	2.9	1.3		2.2		0.9	1.2	0.
Zircon (rounded)	2.6		2.4	3.1	1.6	2.2	3.0	1.9	2.8	0.6	4
Opaques											
Pyrite											
Authigenic TiO_2											
Others											
Wt. percentage of heavy residues	0.71	0.01	0.05	0.09	0.04	0.01	0.06	0.03	0.03	0.16	0

1. brownish green, 2. green-purple, 3. well-rounded.

53071301	Hakobuchi sandstone
53071302'	Do.
53071302	Do.
53071304	Noborikawa coal-bearing formation
53071305	Do.
53071306	Do.
53071307	Do.
53071308	Do.
53071309	Horokabetsu formation
53071310	Do.
53071311	Yubari coal-bearing formation
53071312	Wakkanabe formation

Series 53 Collected from the outcrops along the Tanzan River.

…ations in the Ashibetsu District, the Ishikari Coal Field.

	53071312	53071313	53071401	53071402	53071403	53071404	53071405	53071406	5703—11	53071407	53071408	53071409	5703—1
	4	8	4	3	3	11	2	3		+	1	2	3
	1	1	2	3	+	16	+	8	7			1	4
		+				1		10					
	20	19	48	29	18	12	46	25	14	30	50	46	25
	75	72	46	65	79	60	52	54	79	70	49	51	68
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
5		0.4	0.6								0.7		
								0.7					5.5
						0.7			2.2		0.7		4.5
													3.7
5	12.6	13.0	31.6	28.3	20.4	8.2	41.2	29.0	44.5	18.3	43.2	24.2	30.8
4	11.3	4.6	6.3	14.3	16.0	11.1	5.1	10.1	1.1	9.2	13.1	13.1	1.1
5	0.7	0.8	1.3	0.4			0.6		3.3	0.9	3.3	1.0	1.7
			0.6										
													0.6
												0.5	0.6
		0.4											
3	3.4	5.0	1.3	0.7	4.0	1.5	2.5	1.4	6.6	2.7	3.3	3.5	13.7
9	6.1	0.8	2.5	2.9	3.3	2.2	1.9	2.0	2.2	2.4	2.0	3.1	0.6
2	5.5	26.8	19.6	5.2	6.9	23.7	20.2	8.8	1.1	1.2	9.2	8.6	2.2
	1.7	15.5	9.5	2.2	1.8	7.4	1.9	1.4	2.2	0.3	2.0	1.0	4.9
4													0.6
5	0.7	1.7	0.6	0.4	1.5	1.5		0.7	2.2	0.6	0.7		1.1
1	53.3	29.3	26.0	41.9	43.3	38.5	25.4	40.5	26.7	61.3	19.6	43.0	24.7
	0.7			0.7								0.5	
5	2.0	0.4		0.4	0.4				0.9	0.9	1.3		0.6
2	2.0	1.3		2.6	2.5	5.2	1.3	5.4	6.7	2.4	1.3	1.5	2.7
									1				10
									91				75
									1				5
									7				10
									100				**100**
09	0.17	0.05	0.05	0.06	0.05	0.04	0.05	0.14	4.50	0.01	0.07	0.08	0.21

53071313 Bibai coal-bearing formation
53071401 Woodwardia sandstone
53071402 Do.
53071403 Do.
53071404 Hiragishi formation
53071405 Do.
53071406 Do.
5703—11 Do.
53071407 Ashibetsu coal-bearing formation
53071408 Do.
53071409 Do.
5703—1 Poronai formation

Table 29. Data on Heavy Mineral Analysis of the Upper Cretaceous and the

Sample No.	57082503	57082511	57082513	57082509	57082728′	57082728″	57082729	57082504
Biotite	1	3	5	+	1		2	2
Chlorite			1			1	+	2
Muscovite		1						
Ores	7	4	14	34	31	17	22	36
Others	92	92	80	66	68	82	76	60
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents								
Actinolite								
Allanite		1.5						
Anatase	0.4	1.5	2.6		0.2	3.8	3.1	
Augite	3.5	1.5	0.6			13.4	1.7	4.5
Brookite			0.6	0.2				
Chromite				92.1	88.8	28.8	12.5	0.9
Epidote	69.4	38.7						5.5
Garnet (colourless)	13.6	17.8	28.6	0.2	0.2	1.9	5.6	33.6
Garnet (coloured)	1.9	1.8	4.5		0.2		0.3	3.6
Glaucophane								
Hornblende[1]								
Hornblende[2]								
Hornblende[3]		1.8	1.3			1.9	0.7	0.9
Hornblende (brown)						1.9		
Hypersthene	0.4	2.8	2.6			7.7	1.4	
Oxyhornblende								
Rutile	0.4	0.9	4.5	0.3	1.3	26.2	8.7	2.7
Sphene	3.9	15.0	3.9		0.2		0.3	15.4
Tourmaline[4]	1.2	5.5	13.0			3.8	20.5	2.7
Tourmaline (green)		0.9	5.2		0.8		7.0	0.9
Tourmaline (blue)								
Tourmaline (brown)	0.8	0.6	1.3			1.0	1.0	1.8
Zircon (colourless)	4.2	6.1	24.7	6.4	6.8	7.7	31.3	21.8
Zircon (pink)								
Zircon (brown)		0.3					0.7	
Zircon (purple)[5]	0.4		1.3				0.3	
Zircon (rounded)		3.1	5.2	0.8	1.5	1.9	4.2	5.5
Hematite								
Opaques	33	6	55	8	10	7	24	73
Pyrite	13	14				57	47	
Authigenic TiO_2			23	5	11		5	7
Others	54	80	22	87	79	36	24	20
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.32	0.14	0.70	0.53	0.42	0.02	0.41	0.06

1. pale green, 2. bluish green, 3. brownish green, 4.

57082503	Nakagawa formation
57082511	Urakawa formation
57082513	Noborikawa formation
57082509	Yubari formation
57082728′	Do.
57082728″	Wakkanabe formation
57082729	Do.
57082504	Ikushumbetsu formation
530704Wz	Do.
57082502	Do.
57082501	Poronai formation

Tertiary Formations in the Yubari District, the Ishikari Coal Field.

530704Wz	57082502	57082501	57082730	57082749	57082625	57082618	57082619	57082623	57082622	57082617	57082617′	57082616
1	3		4	1				1	1	2	+	1
2		8	10	3				3	1	4	2	
+											1	1
63	21	49	30	28	1	44	7	43	28	68	78	83
34	76	43	56	68	99	56	93	53	70	26	19	15
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
									0.5	0.7		
3.5											1.2	
	0.6	2.9		2.2				37.1	30.2		1.8	2.2
4.0		23.0	53.8	11.0	92.7	81.4	99.1	11.7	19.7	13.5	11.4	3.3
				1.1								
0.5	10.5	10.1	9.6	1.1		0.2		23.0	12.6	34.6	40.1	36.4
18.0										8.3	6.0	2.2
20.5	40.9	13.0	1.9	9.9		0.4		3.2	8.6	12.0	14.4	18.7
2.0	1.2	1.3	1.9					0.4	2.5	8.3	1.2	6.6
											1.2	1.1
0.5			1.9								1.2	2.2
						0.6						
1.0		2.9	5.8	2.2	6.7	10.6	0.9	1.6	3.0	5.3	1.2	1.1
		2.9			0.6							
	0.6	7.2	23.1	5.5				12.9	0.5	1.5	1.2	3.3
0.5	2.9	2.9		5.5		2.5					2.4	2.2
4.0	1.8	2.9		5.5				1.2	0.5	1.5	2.4	1.1
5.5	2.3	1.3		12.1				3.2	2.5	3.8	1.8	1.1
1.0		1.3		8.8					2.0			2.2
												1.1
1.0	6.4	1.3		3.3					1.5		0.6	
30.0	26.4	18.8	1.9	20.9		2.9		4.8	13.2	8.3	9.0	14.4
0.5						0.2			0.5	0.7	0.6	
1.0	1.2	2.9										
6.5	5.3	4.3		11.0		1.0		0.8	2.0	1.4	2.4	1.1
		1	3				1	5	2			1
5	26	13	65	5	5	7	1	15	1	17	14	13
47	42	66	24	89	+	51	2	33	86	17	20	16
	2	4							1		2	1
48	30	16	8	6	95	42	96	47	10	66	64	39
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	0.04	0.23	0.10	0.70	2.90	0.20	7.16	0.11	0.20	0.35	0.18	0.20

green-purple, 5. well-rounded.

57082730 Poronai formation
57082749 Do.
57082625 Momijiyama formation, collected from the outcrops along the Yubari River
57082618 Do.
57082619 Takinoue formatoin
57082623 Do.
57082622 Do.
57082617 Kawabata formation
57082617′ Do.
57082616 Do.

Table 30. Data on Heavy Mineral Analysis of the T

Sample No.	5307-I-02	57090301	57090508	57090506	57090503
Biotite	2	64	4	1	2
Chlorite	+	28	1	1	+
Muscovite	+	1	1		
Ores	56	5	66	15	59
Others	42	2	28	83	39
	100	**100**	**100**	**100**	**100**
Other Constituents					
Actinolite			1.8		2.7
Allanite		6.2	0.9		
Anatase	4.5		0.9		1.4
Augite	0.2	12.5	8.2	36.6	5.0
Brookite	1.8				
Chromite	0.5		4.5		5.4
Epidote			12.7		6.3
Garnet (colourless)	11.4	50.0	17.3		4.6
Garnet (coloured)	1.1				0.8
Glaucophane		6.2	1.8		3.2
Hornblende[1]					
Hornblende[2]		6.2	15.4	0.9	23.8
Hornblende[3]	0.2		26.4	7.2	35.6
Hornblende (brown)					7.2
Hypersthene				55.3	
Oxyhornblende					
Rutile	4.3		0.9		
Sphene	1.1		0.9		
Tourmaline[4]	14.9	6.2			
Tourmaline (green)	4.7				
Tourmaline (blue)	0.2				
Tourmaline (brown)	2.9				
Zircon (colourless)	45.5	6.2	4.5		4.1
Zircon (pink)	0.5		0.9		
Zircon (brown)	0.9				
Zircon (purple)[5]	0.9				
Zircon (rounded)	4.3	6.2	2.7		
Opaques	22	4			
Pyrite	1	3			
Authigenic TiO_2	2				
Others	75	93			
	100	**100**			
Wt. percentage of heavy residues		0.56	0.07	8.38	0.17

1. pale green, 2. bluish green, 3. brownish green, 4. green-

5307-I-02 Asahi coal-bearing fo
57090301 Kawabata formation
57090508 Do.
57090506 Do.
57090503 Do.
57090501 Do.
57090904 Iwamizawa formatio

tiary Formations in the Kuriyama-Kurisawa District.

	57090904	57090903	57081504	57091903	57083101	5709300w	570930Tk
		1	1	5		1	1
	2	+	1		1	3	
	21	22	13	35	19	8	10
	77	76	85	60	80	88	89
	100	**100**	**100**	**100**	**100**	**100**	**100**
.7	4.4	0.8	2.0	0.9	3.5		
						0.4	
.3	4.4	2.5	2.7		20.9	5.8	8.0
.8	2.9	0.8	1.3	7.3	1.2	2.5	
.4	7.4	10.8	10.7	4.6	3.5	8.2	
.8	0.7	0.8	0.7	2.8		0.4	
.9							
	7.4	2.5	3.3	3.7	1.2	4.1	
						7.0	2.0
.3	19.1	10.0	10.7	44.1	26.8	9.4	1.5
.3	44.9	60.8	50.7	21.1	16.3	56.2	75.0
.6	8.1	5.8	10.0	11.0	5.8	4.9	0.5
			0.7		14.0	0.4	10.5
		2.5	6.7		4.7		2.0
		0.8		1.8			
		0.8		0.9	1.2	0.4	
.9	0.7	0.8	0.7	1.8	1.2	0.4	0.5
.9							
2.47	1.44	0.55	0.12	0.13	1.00	0.73	0.60

rple, 5. well-rounded.

nation, collected at the Asahi Colliery

57090903	Iwamizawa formation
57081504	Kamogawa formation
57091903	Do.
57083101	Kuriyama formation
5709300w	Do.
570930Tk	Kiyomappu sandstone

Collected by Y. SUZUKI, exclusive of 5307-I-2.

APPENDIX II

Data on Heavy Mineral Analysis of the Upper Cretaceous and the Tertiary Formations in the Kushiro Coal Field

Table 31. Data on Heavy Mineral Analysis of the Palaeogene Formations in the Kamicharo District, the Kushiro Coal Field.

Sample No.	551105105	551105104	551105103	551105102	551105101
Biotite		2		2	3
Chlorite	3	5	6	2	6
Ores	26	15	28	21	60
Others	71	78	66	75	31
	100	**100**	**100**	**100**	**100**
Other Constituents					
Actinolite	10.3				
Allanite				0.5	
Anatase				2.6	
Augite	6.5		1.0	0.5	2.9
Chromite		2.5	12.0	4.2	38.4
Diallage	9.7				
Diopside	25.3		2.0		
Epidote	4.9	56.2	75.0	2.6	1.0
Garnet (colourless)		5.0	1.0	1.5	24.3
Garnet (coloured)			2.0	1.5	4.1
Hornblende[1]	29.5			0.5	
Hornblende (brown)	13.5				
Hypersthene					3.0
Rutile		2.5		2.1	2.0
Sphene		11.6	3.0		1.0
Tourmaline[2]		7.4	2.0	42.2	8.1
Tourmaline (green)		1.6	1.0	14.6	1.0
Tourmaline (brown)					1.0
Zircon (colourless)	0.5	11.5	1.0	26.6	13.2
Zircon (brown)					1.0
Zircon (rounded)		1.7		0.5	
Zoisite	?				
Opaques	24	13	11	20	37
Authigenic TiO_2				8	1
Others	76	87	89	72	62
	100	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	6.57	0.34	0.77	0.10	0.05

551105105 Upper part of the Rushin formation
551105104 Middle part of the Yubetsu formation
551105103 Shitakara formation
551105102 "Hatokuso" conglomerate of the Shakubetsu formation
551105101 Omagari sandstone of the Charo formation

Collected from the outcrops along the Shutonaizawa, a branch of the Charo River.

1. brownish green, 2. green-purple.

Table 32. Data on Heavy Mineral Analysis of the Tertiary Formations in the Yubetsu District.

Sample No.	551105Ht	551105Yb	551105Yb′	551105Sk	551105Sb	551105Om	55110501	55110502	55110503
Biotite	1	8	2	24	31	4			
Chlorite	2	18	5	10	14	5	1	1	
Muscovite					1				
Ores	1	1	1	38	4	5	9	4	45
Others	96	73	92	28	40	86	90	95	55
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents									
Allanite	1.4	3.8	0.5			1.4			
Anatase	0.5	0.4	1.6		2.6	2.9			
Augite			0.5	10.0	2.1	0.9	12.5	52.5	53.3
Brookite		0.4		1.1	1.0	2.5			
Chromite				1.1		0.4		0.6	
Epidote	68.0	0.4	0.5	2.2	0.5	0.4		2.3	
Garnet (colourless)	1.4	15.6	6.6	8.8	11.7	12.8		0.6	
Garnet (coloured)	0.5	0.4	0.5		0.5				
Hornblende[1]	0.5	1.2	0.5	1.1	2.1	0.9	53.6	15.4	1.3
Hornblende (brown)	0.5	1.2		4.5	1.5		2.3	2.3	
Hypersthene		0.4		20.1	4.1	0.4	31.7	26.3	44.7
Rutile		1.0	1.0	2.2	5.1	2.5			
Sphene	8.8	1.2	0.5			0.4			
Spinel						0.4			
Topaz						0.9			
Tourmaline[2]	2.3	1.9	12.1	10.0	13.3	9.3			
Tourmaline (green)		1.9	3.0	3.3	6.1	1.4			
Tourmaline (brown)		4.7	1.6	3.3	0.5	1.4			
Zircon (colourless)	14.5	56.6	62.0	25.7	42.4	51.7			0.7
Zircon (pink)		1.0	0.5						
Zircon (brown)		0.8		1.1	0.5				
Zircon (rounded)	0.9	7.1	8.7	5.5	6.1	9.4			
Zoisite	0.9								
Hematite						1			
Opaques	8	14	16	17	8	20	8	8	11
Pyrite				1	1				
Authigenic TiO_2	1	4	2	+	1	2			
Others	91	82	82	82	90	77	92	92	89
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.33	0.10	0.10	0.03	0.04	0.09	1.20	0.33	1.61

1. brownish green, 2. green-purple.

551105Ht Harutori coal-bearing formation
551105Yb Yubetsu coal-bearing formation
551105Yb′ Do.
551105Sk Shitakara formation
551105Sb Shakubetsu formation
551105Om Omagari sandstone
55110501 Hombetsu formation
55110502 Do.
55110503 Do.

551105Ht–551105Om Collected from the outcrops along the Berutsunai River.
55110501–03 Collected from the outcrops along the Okuyokunnaizawa.

Table 33. Data on Heavy Mineral Analysis of the Upper Cretaceous and t

Sample No.	551010Cr	540927Cr	540927Rs	540927Rs'	540928Rs	54092801	54092802	54092101	54092102	54092103	54102601
Biotite	1	1	1	1		3	3	1	2	1	1
Chlorite	1	1	10	17	3	8	1	1	15	1	1
Muscovite						2	11	1			1
Ores	5	30	12	2	4	23	22	7	33	93	74
Others	93	68	77	81	93	64	63	90	50	5	23
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents											
Actinolite				9.4	5.4						
Allanite			1.0				1.3		0.4		0.4
Anatase						0.5			0.4		0.4
Augite	88.2	53.7	3.0	1.3	1.2	0.3	0.4				
Brookite						0.3	0.4				
Chromite			3.0		3.0	16.7	8.9	4.0	38.8	13.2	33.7
Diallage				7.5	20.8						
Diopside				25.0	33.3	1.6	0.4	1.3	0.4		
Epidote	1.0	6.9	82.0	4.4	6.5	1.0	14.3	70.2	23.4		
Garnet (colourless)			3.0			5.3	10.6	3.3	4.3	25.8	16.9
Garnet (coloured)									1.3	0.3	1.0
Hornblende (br. green)	8.9	36.2		40.6	25.0	0.5	0.9				
Hornblende (brown)	1.9	1.1		11.2	4.8	0.3	0.9	0.6	0.4		
Hypersthene							0.9				
Olivine				0.6							
Oxyhornblende											
Rutile			1.0			5.8	1.3	0.6	0.9	0.7	2.8
Sphene						1.1	17.9	6.0	9.3	1.3	
Spinel									0.4		0.4
Topaz						?		?	0.4		
Tourmaline (grn-purp.)		0.5	3.0			16.2	7.1	1.3	8.0		10.6
Tourmaline (green)			1.0			10.6	1.8	0.6	3.5		5.1
Tourmaline (brown)		1.6	3.0			0.8	1.8	0.6	0.9		1.9
Zircon (colourless)						32.3	25.2	10.0	7.0	52.4	23.9
Zircon (pink)									0.4		0.4
Zircon (brown)							0.4			1.3	
Zircon (rounded)						6.7	5.3	0.6	0.4	5.3	1.9
Zoisite								0.6	0.4		
Opaques	4	5	9	5	7	18	28	15	19	11	17
Pyrite								2			
Authigenic TiO_2						1	+	+	+		+
Others	96	95	91	95	93	81	72	83	81	89	83
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.40	1.47	2.30	7.49	0.36	0.09	0.05	0.80	0.26	0.66	0.13

551010Cr Sensho group, Upper Cretaceous
540927Cr Do.
540927Rs Rushin formation
540927Rs' Do.
540928Rs Do.
54092801 Yubetsu coal-bearing formation
54092802 Shitakara formation
54092101 Do.
54092102 Do.

he Tertiary Formations in the Urahoro-Shakubetsu-Atsunai-Ombetsu District.

54090601	54090501	54092803	54101901	54091701	54092401	551021330	55100901	550921269	55091301	550915259	550915255	550910214	540824Sn
3	1	1	1	1			2	3		20	8	2	1
5	2	1		1									
3	5												
35	68	95	90	4	7	41	31	7	13	19	3	3	12
34	24	3	9	94	93	59	67	90	87	61	89	95	87
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
0.9	3.1									1.0			
0.3				0.5	77.5	85.0	48.6	35.5	46.5	13.3	32.0	39.8	45.9
0.3	1.5												
29.5	10.8	8.0	4.7										
0.6													
0.3										1.0			3.2
13.7	15.0	16.0	13.5	0.3		1.0	1.0	0.8		0.9			0.9
4.0			2.4										
			6.5	74.1	18.5	7.0	38.1	4.1	17.6	69.6	31.0	18.3	22.6
			1.8	23.6	3.0	5.0	3.8		4.9	6.7	21.8	13.1	0.9
		4.0	0.6			1.0	5.7	59.6	31.0	5.7	14.3	25.5	26.1
												0.7	
				1.1	1.0	1.0	1.0				0.9	2.6	
2.2	2.1												
0.6	0.5		47.0	0.3									
0.3													
16.2	9.8												
			2.4										
4.3	6.2		1.2										
1.8	1.5	4.0											
25.9	43.4	52.0	17.6				1.9			0.9			
	0.5												
2.7	4.6	12.0	2.4	0.3						0.9			0.4
25	13	7	9	1	1	6	4	1	2	6	1	1	3
9	1	26	11	12			45						
1													
65	86	67	80	87	99	94	51	99	98	94	99	99	97
100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
0.07	0.16	0.32	0.40	0.74	20.27	57.70	1.34	1.40	2.23	0.33	4.67	4.07	6.37

54092103 Shakubetsu coal-bearing formation
54102601 Do.
54090601 Omagari sandstone
54090501 Do.
54092803 Do.
54101901 Charo formation
54091701 Nuibetsu formation
54092401 Chokubetsu formation
551021330 Do.
55100901 Chokubetsu formation
550921269 Atsunai formation
55091301 Do.
550915259 Do.
550915255 Shiranuka formation
550910214 Do.
540824Sn Do.

Table 34. Data on Heavy Mineral Analysis of the Upper Cretaceous and the T

Sample No.	55110201	55110202	55110203	Ht-2	Ht-3	Ht-4	K6-218	K6-209
Biotite	15	5	2	11	11	5	5	7
Chlorite	4	9	7	17	7	3	21	9
Muscovite	1			2		2	1	1
Ores	24	64	67	25	43	23	43	38
Others	56	22	24	45	39	67	30	45
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents								
Allanite	1.4	1.0		1.7	4.3	0.6	5.2	2.9
Anatase				1.7		1.9		
Augite	5.5	3.8		1.1		4.3		
Chromite								
Diallage								
Diopside								
Epidote	60.6	6.7	10.8	6.2	7.9	1.2	3.5	23.2
Garnet (colourless)	5.5	1.0	2.4	24.0	28.8	8.6	11.0	2.2
Garnet (coloured)			3.6	14.2	6.5	7.4	1.8	0.7
Hornblende[1]								
Hornblende[2]	13.1	67.2	78.4	0.6	0.7	2.5		
Hornblende (brown)		10.6	1.2	2.2	2.9	1.9		?
Hypersthene	0.7	?	1.2	2.2		4.9		
Rutile				3.4	1.4	3.7	0.6	0.7
Sphene	2.8	6.7	2.4	20.4	18.7	6.8	25.6	29.0
Spinel								
Tourmaline[3]	0.7			3.9	2.9	5.6	2.3	
Tourmaline (green)								
Tourmaline (blue)								
Tourmaline (brown)				0.6		0.6		
Zircon (colourless)	9.0	2.0		13.5	24.5	49.0	49.4	40.6
Zircon (pink)						0.6		
Zircon (rounded)	0.7	1.0		2.2	1.4			
Zoisite				1.1		0.6	0.6	0.7
Hematite								
Opaques	10	42	42	36	43	39	15	13
Pyrite		2						
Authigenic TiO_2		1	1		1			
Others	90	55	57	64	56	61	85	87
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.76	1.45	2.18	0.42	0.33	0.24	0.17	0.06

1. bluish green, 2. brownish green, 3. green-purple.

55110201	Upper Cretaceous formation	K6-209	Ha
55110202	Beppo conglomerate	K6-206	Te
55110203	Harutori coal-bearing formation	K6-195	Do
Ht-2	Do.	K6-184	Do
Ht-3	Do.	K6-151	Do
Ht-4	Do.	K6-142	Do
K6-218	Do.	K6-126	Do

55110201 to Ht-4 Collected on the Osotsunai Beach.

Series K6 Collected from the cores of the Katsurakoi No. 6 drilling.

Series T19 Collected from the cores of the Taiheiyo No. 19 drilling.

rtiary Formations in the Harutori District.

K6-20…	K6-195	K6-184	K6-151	K6-142	K6-126	K6-106	K6-104	K6- 95	K6- 66	K6- 38	T19- 1	T19- 2
5	7	2	2	3	5	3	3	15	2	3	5	10
33	8	47	18	6	6	17	1	14	6	11	5	10
1						1	1	1		1		2
35	5	9	12	10	10	15	25	5	15	45	25	19
26	80	42	68	81	79	64	70	65	77	40	65	59
00	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
6.0		2.9	1.1	0.6		2.8	1.1	1.7		1.2		1.8
											1.5	0.5
	.6				0.6					0.6		0.5
5.0	2.4	11.4	1.1	2.9	1.1	7.6	1.6	0.9	0.9	0.6	1.5	12.9
					8.9						3.7	
26.0	54.9	65.7	67.1	71.7	34.6	40.2	77.2	61.5	74.8	55.5	63.2	57.3
3.0		2.9		1.8	1.1	1.9	1.1	1.7	1.7	3.0	3.1	2.3
1.0				0.6								0.9
	16.2	5.7	5.7	1.2	16.5	10.4						
1.0	4.0				22.7	12.4					0.8	0.5
	3.2		1.1		1.1		0.5			0.6	0.8	
2.0								0.9		0.6	1.5	0.5
8.0	2.4	2.9	3.4	4.7	4.5	4.7	9.0	12.8	7.8	17.5	6.2	8.6
							?					
0.0	4.8		2.3	2.9		4.7	4.2	2.6	1.7	1.2	2.3	
										0.6		1.8
					0.6					0.6	0.8	
1.0	0.8	2.9	8.0	4.7	2.2	12.3	1.1	11.9	4.4	9.0	3.8	5.0
				2.4	1.1		0.5		0.9	1.2		1.8
7.0	5.7	5.6	10.2	6.5	5.0	3.2	3.7	6.0	7.8	7.8	10.8	5.5
											58	27
5	11	47	26	18	19	10						
						2	13	9	9	5		
						+						+
5	89	53	74	82	81	88						
0	**100**	**100**	**100**	**100**	**100**	**100**						
0.27	1.68	2.96	1.21	1.16	1.74	0.36	0.79	0.39	0.52	0.23	0.43	0.54

tori formation
eru formation

K6–106 Tenneru formation
K6–104 Yubetsu coal-bearing formation
K6– 95 Do.
K6– 66 Do.
K6– 38 Do.
K19– 1 Shimizu shale
K19– 2 Yonemachi sandstone

Table 35. Data on Heavy Mineral Analysis of the Upper Cretaceous and

Sample No.	521001Cr	521001Bp	535	521001Tn	520928-2	520928-1	520927Yb	587
Biotite	14	1	1	1	2	4	2	6
Chlorite	14	1	6	4	1	1	1	2
Muscovite						1		
Ores	7	12	13	8	29	2	1	3
Others	65	86	80	87	68	92	96	89
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Other Constituents								
Actinolite			6.0					
Allanite				2.4	6.8	4.7	9.5	1.
Anatase					0.6	1.4		0.
Augite	+		6.0	0.6		0.9		
Brookite						1.1		
Chromite			4.5					1.
Clinozoisite								
Diallage			11.2					
Diopside			11.9	0.6				
Epidote	69.4	71.6	14.9	76.0	?	1.4	0.5	28.
Garnet (colourless)		1.9		1.2	7.3	6.0	10.0	3.
Garnet (coloured)		0.7			1.2	0.8	3.0	0.
Hornblende (pale green)								
Hornblende (bluish green)			38.8	10.1				
Hornblende (brownish green)	10.2	2.0	2.2	1.8				
Hornblende (brown)			4.5	1.8				
Hypersthene						2.5		0.
Oxyhornblende								
Rutile					0.9	2.2	1.0	0.
Sphene		1.3		1.2	31.1	34.0	26.5	26.
Spinel		0.7						
Tourmaline (green-purple)		1.9			1.9	4.7	6.0	16.
Tourmaline (green)		1.9			1.2	1.9	2.0	3.
Tourmaline (blue)		1.3				0.3		0.
Tourmaline (brown)				0.6	1.8	1.1	7.5	0.
Zircon (colourless)	20.4	12.2		3.0	45.8	34.3	29.5	13.
Zircon (pink)								
Zircon (brown)							0.5	
Zircon (rounded)				0·6	1.5	2.7	4.0	1.
Zoisite		4.5						
Hematite								
Opaques	1	16	13	8	9	13	5	9
Pyrite	85		1				1	2
Authigenic TiO_2				2		+	25	+
Others	14	84	86	90	91	87	69	89
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Wt. percentage of heavy residues	0.05	0.27	6.03	0.57	0.25	0.01	0.04	0.

521001Cr Upper Cretaceous formation
521001Bp Beppo conglomerate of the Harutori formation
535 Tenneru formation
521001Tn Do.
520928-2 Yubetsu formation
520928-1 Do.
520927Yb Yub
587 Do.
88 Do.
483 (2) Do.
621 Shit
451 (2) Do.

the Tertiary Formations in the Nuibetsu District.

	88	483 (2)	621	451 (2)	297	520828Sk	520922Sb	2	520828 Nb	215
	2	6	2	3		13	16	2		
	2	3	1	1	2		16	1		
	2	1	8	32	27	5	50	33	24	84
	94	90	89	64	71	82	18	64	76	16
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
				0.7	3.4					
6		0.3	7.3	5.3	0.7	0.7	10.5	0.9		
4	0.5	0.9								
			1.2	2.1	0.7	2.3		1.0	61.0	4.2
		0.3								
2	1.1		0.6		1.4					
				0.7						
5				18.5	59.2					
6	6.7	6.8	26.1	15.2	2.0	17.9	15.8	2.7		
4	2.6	1.5	6.0	7.3	0.7	1.5	15.8	4.1		
				0.7						
						0.7			24.8	79.1
		0.3							5.9	4.2
4			0.6	1.3		2.3		2.7		
									7.7	
4	1.1	1.5	1.2	2.6	0.7	0.7		0.9		
8	0.5	0.9	13.9	23.2	17.0	3.1	36.8	61.5		
		0.6						0.5		
5	5.0	5.6	6.7	3.3	2.7	8.5	5.3	1.4		
3	1.1	1.9			0.7	0.7		0.9		
3	0.5									
8	1.1	0.6	1.8	4.6	0.7	3.1		0.5		
7	75.8	73.9	31.6	5.3	7.4	57.8	15.8	22.0	0.6	8.3
						0.7				
		0.3								
5	3.8	4.6	3.0	7.3	0.7					4.2
				2.0	2.0			0.9		
						1			15	
	16	4	12	9	15	37	2	12	5	19
	2	1	6	2	1	7	92	6	1	31
		1	32	21		3				
	72	94	50	68	84	52	6	82	79	50
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
0	0.10	0.05	0.04	0.05	0.20	0.01	0.57	0.03	3.54	0.38

tsu formation

kara formation

297	Shitakara formation
520828Sk	Do.
520922Sb	Shakubetsu formation
2	Charo formation
520828Nb	Nuibetsu formation
215	Basal glauconite sandstone of the Chokubetsu formation

ON SOME ORDOVICIAN FOSSILS FROM NORTHERN MALAYA AND HER ADJACENCE

By

Teiichi KOBAYASHI

With Plates XXIV–XXVII.

Lately I have described several Ordovician fossils collected from the Thailand-Malayan borderland by Mr. Saman BURAVAS, chief geologist of the Royal Department of Mines, Bangkok, Thailand (1958). Subsequently another collection was sent from the Geological Survey, Federation of Malaya, at Ipoh and this is the result of study.

According to Mr. Olive R. JONES, geologist of the survey, who made the collection, the fossiliferous formation of the Langkawi islands and the neighbourhood which he called "Setul formation" is tentatively divided into five parts in descending order as follows:

S_5. Upper bedded gray limestone, richly fossiliferous........1,000′ thick.

S_4. Bedded limestone with shale lenses containing graptolites........1,500′ thick.

S_3. Thickly bedded grey limestone with occasional fossiliferous horizons containing cephalopods and gastropods ....3,000′ thick.

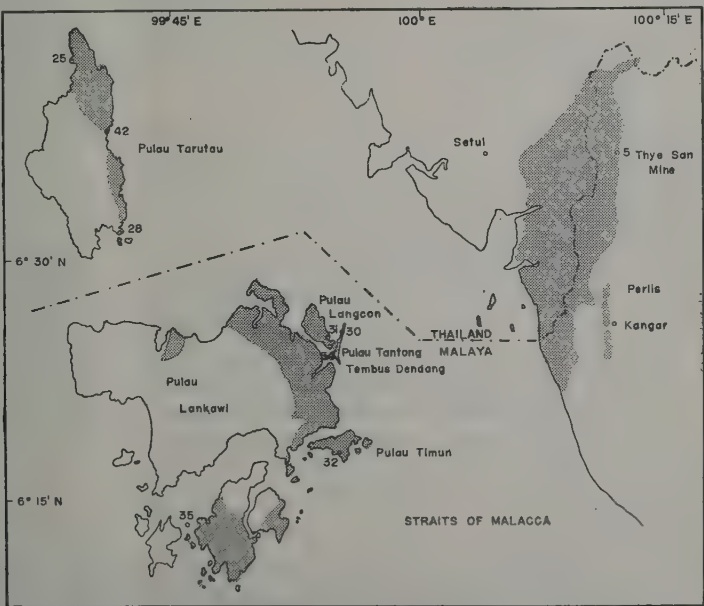

Figure 1. Map showing fossil localities (small circles) and Distribution of the Setul formation (shade).

Received Dec. 24, 1958: read at the 72nd meeting of the Palaeotological Society of Japan at Hiroshima, Feb. 14, 1959.

S_2. Massive white unfossiliferous limestone ....2,000′ thick.
S_1. Light coloured bedded limestone with brachiopods and some other fossils...100–200′ thick.

The Setul formation may be 7,500 to 8,000 feet or 2,300 to 2,500 meters in total thickness. It is underlain conformably by quartzites and shales which yield Upper Cambrian fossils at Tarutau island as I have described in a recent paper (1957). The fossils described in this paper were mostly collected from the middle limestone or the division S_3 at some localities on the Langkawi islands, Tarutau island and Perlis on the peninsula. (See Text-figure 1). They are shown in the table 1.

Armenoceras chediforme was first described from the Thung Song limestone at Ron Phibon near Thung Song in Peninsular Thailand. Three specimens of this species were procured at loc. 5, Thye San mine, northwest of Perlis. There they are accompanied by *Ormoceras* sp. indt. and *Lytospira rectangularis* which the last is closely allied to *L. norvegica* from the Llandeilian *Ogygiaschiefer* of Oslo, Norway. However, I have seen no *Armenoceras* in Eastern Asia which is older than Toufangian, or the Machiakou limestone in North China and the Tsuibon limestone in South Korea. In North America the genus most flourished in the Red River formation (FLOWER, 1957). The age of this faunule is probably Black River or younger.

The gastropod limestone of the Langkawi islands yields a copious fauna comprising the following fossils:

Hormotoma (?) spp. indt.
Helicotoma jonesi
Helicotoma (?) *costata*
Palaeomphalus giganteus
Lesueurilla zonata
Lesueurilla (?) sp. indt.
Malayaspira rugosa
Malayaspira (?) sp. indt.
Endoceras (?) sp. indt.
Ormoceras langkawiense
Discoceras (*Hardmanoceras*?) *chrysanthimum*
Discoceras (*Hardmanoceras*?) *laeviventrum*

They were collected from four localities (Locs. 30, 31, 32 and 34). *Malayaspira rugosa* occurs at all of these localities and *Helicotoma jonesi* and *Hormotoma* (?) sp. indt. are found at locs. 31 and 34 of Lulau Langgon. Therefore the fossil beds of these four localities must be contemporaneous with one another. It is further noteworthy that these beds are not much apart from the fossil bed at Kangar, Perlis, in geological age, whence the following four species were procured, because two of them are common with the above fauna.

Malayaspira rugosa
Ormoceras langkawiense
Actinoceras perlisense
Actinoceras sp. indt.

Thus the Langkawi gastropod fauna combined with the Kangar faunule consists of 9 species of gastropods and 6 of nautiloids beside an indeterminable form.

Helicotoma jonesi is a common gastropod which is intermediate between *H. sinensis* and *H. louderbacki*, if the sunken spires of these Chinese species are ignored. *H. sinensis* is a common membr of the early Neichiashan fauna the age of which is Llandeilian. *Helicotoma* (?) *costata* is allied to *H. ichimurai* from the Shorin formation in North Korea which is considered late Lower Ordovician, but distinct

ribs on the basal side of the whorl represent a remarkable characteristic of *costata*. In the Eastern Asiatic faunas the nearest to *Palaeomphalus giganteus* is *P. keizanensis* from the Tsuibon limestone of South Korea which is considered Caradocian in age.

None of the Asiatic gastropods appears to be close to *Lesueurilla zonata*, but it bears similarities to *Lecanospira* which suggests its possible derivation from this late Canadian genus. Among the Baltic gastropods, however, *L. helix* and *L. dilatata* from the *Vaginatenkalk* reveal resemblances with *zonata*, although *zonata* has zonal sculptures in the lower part of the whorl which are quite strange for *Lesueurilla* as well as *Lecanospira*. It is further a remarkable fact that *Palaeomphalus giganteus* agrees with "*Raphistoma*" *qualterium* and "*R.*" *scalitoides* both from the *Vaginatenkalk* in one or the other character. The resemblance of *H. jonesi* with "*R.*" *schmidti* from the *Orthocerenkalk* of the Oslo district, Norwey can hardly be overlooked.

In Central China *Helicotoma sinensis* is often found associated with *Discoceras eurasiaticum* in the Neichiashan formation. Likewise, *H. jonesi* is found together with two species of *Discoceras* at loc. 31. These nautiloids, however, bear similarities with *Hardmanoceras* which is so far endemic to Northwestern Australia in the late Canadian. The Malayan forms of *Discoceras* are, however, apparently more advanced than *Hardmanoceras lobatum* in the effacement of the radial ribs. Therefore it is reasonable to consider that the Australian form is a little older than the Malayan one.

According to Flower (1957) the oldest *Ormoceras* appears in the Chazyan in North America. In Eastern Asia *Actinoceras* occurs in the Toufangian, but most of the so-called *Actinoceras* in the Toufangian are better placed in *Armenoceras* or *Ormoceras*.

If emphasis is laid on the inclusion of the two species of *Actinoceras* in the Kangar faunule, its age may not be older than the Toufangian or Black River of North America. *Actinoceras* is, however, as yet unknown from the gastropod limestone of Langkawi and the majority of gastropods suggests Llandeilian or Chazyan for the age of its fauna.

Sinuitopsis cfr. *kochiriensis* is a solitary gastropod found at loc. 42, Wanderer bay, L. Tarutau. *S. kochiriensis* is a member of the Chikunsan fauna in South Korea whose age is Llandeilian.

Endoceroid, gen. and sp. indt. from loc. 28 on the south coast of L. Tarutau is too fragmentary to discuss the chronology.

In summarizing the above discussion, it is concluded that

1. The gastropod limestone of Langkawi is probably correlated to the Neichiashan formation of Central China and the *Vaginatenkalk* of the Baltic region.
2. *Sinuitopsis* cfr. *kochiriensis* bearing horizon of L. Tarutau may be Llandeilian and close to the preceding.
3. The *Actinoceras* limestone of Kangar, Perlis, is probably a little younger than the gastropod limestone of Langkawi.
4. The *Armenoceras* limestone at Roh Phibon and Thye San mine is not older than Toufangian and most probably coeval with the Mohawkian or Black River-Trenton in North America.

The present collection contains an Obolid and Orthid brachipod (Nos. 40 and 41) and a sponge (No. 29) from the basal limestone or S_1 division of Pulau Jong (loc. 35). The sponge is, like *Archaeoscyphia*, conical, but much longer and slender and not annulated. Unfortunately they are all imperfect to carry

out a presise determination. The limestone is, however, most probably Lower Ordovician because the quartzite and shale formation which lies beneath the

Number in brackets: Locality Number

Number without brackets: Specimen number in JONES' collection

Diagonal cross: Specimen in BURAVAS' collection

	Malaya					Thailand		
	Perlis	Langkawi islands				Bulau Terutau		
		Pulau Langgon		P. Tangong Tembus Dendang				
	Kangar Thye San Mine (loc. 5)	East coast (31)	South end (34)	Northern part (30)	Pulau Timun (32)	Wanderer Bay (42)	South coast (28)	Ron Phibon
Hormotoma (?) spp. indt.		22	19, 20, 21					
Sinuitopsis cf. *kochiriensis*						11		
Helicotoma jonesi		7, 10	18	6				
Helicotoma (?) *costata*				9				
Palaeomphalus giganteus			14, 16, 17					
Lesueurilla zonata		7						
Lesueurilla (?) sp. indt.			13					
Malayaspira rugosa	×	8	2, 15	4, 6	5			
Malayaspira (?) sp. indt.			13					
Lytospira rectangularis	37							
Endoceras (?) sp. indt.		28						
Endoceroid, gen. et sp. indt.							27	
Ormoceras langskawiense	×			25				
Ormoceras sp. indt.	24							
Armenoceras chediforme	30, 31, 32							×
Actinoceras perlisense	×							
Actinoceras sp. indt.	×							
Discoceras (*Hardmanoceras* ?) *chrysanthimum*		3						
D. (H.?) *laeviventrum*		12						

Table 1. List or Ordovician fossils from the Thung Song limestone or/and the Middle limestone of the Setul formation.

(a) (b)

Fig. 2. Two indeterminable Sponges.
a. *Archaeoscyphia*-like sponge from loc. 35, (Specimen 29), ×2
b. Same specimen. (No. 29), ×5

limestone is correlated to the fossiliferous Upper Cambrian of Tarutau island.

On Palau Langgon and Palau Tanjong Tembus Dendang graptolite shales are inserted in the Setul formation. Graptolites from the latter island are not well preserved, but BULMAN noted that there are

1. *Glyptograptus* or *Orthograptus* of *calcaratus* type suggesting high Ordovician for its age, and
2. *Monograptus* resembling *concinnus* or *regularis* of the Llandovery.

BALL and STRACHAN indentified a well preserved graptolites from the former island with *Monograptus clingani* of the middle Llandovery. On the basis of these finds JONES (1957) considered that the S_4 zone of the Setul formation is in a range from Caradocian to middle Llandovery.

The fossiliferous limestone of S_5 must be younger, but I cannot express any opinion for its chronology, because the collection comprises none from this division.

For the time being it is reasonable to consider that the Setul formation belongs wholly to the Silurian of the sense by MURCHISON. Its major part is, however, Ordovician and the boundary between the Ordovician and Gotlandian or Silurian of the narrow sense by LAPWORTH must be somewhere in the S_4 division.

Returning to the gastropods from the Langkawi limestone, it is a remarkable fact that the radial sculptures are sometimes unusually strong on the basal side but become weak or completely obsolete on the other side, as examplified by *Malayaspira rugosa*, *Lesueurilla zonata* and *Helicotoma* (?) *costata*. This mode of ornamentation is so rare in *Lesueurilla* and *Helicotoma* that I deem that these species may be segregated from these genera in future when a rich material can be examined.

Not only the affinity of *Helicotoma jonesi* with *R.* cfr. *sinensis* by GORTANI (1934), but the occurrence of endoceroids also suggest some alliance of the Langkawi fauna to the Llandeilian limestone fauna in Caracorum. There the gastropod limestone with *Raphistoma qualterium*, *R.* cfr. *sinensis*, *Lesueurilla de-filippi* and others lies on the cephalopod limestone containing *Vaginoceras* and *Orthoceras*.

It is certain that the Himalayan geosyncline was the main route of migration through Eurasia, but the route to the west of Caracorum is obscure. Gastropods and cephalopods are apparently uncommon in the Ordovician formations in

Central Asia and the Ural mountains, although *Endoceras* is reported to occur in these regions and *Lophospira*, *Cyclonema* and *Orthoceras* is known from Kazakstan (BELIAEVSKY et al., 1958). Incidentally, *Lophospira* is not restricted to the Arcto-American-East Asiatic provinces. Many KOKEN's species of *Worthenia* from the Baltic Ordovician were transferred by TEICHERT (1932) to this genus. *Lophospira* and *Pagodispira* or *Donaldiella* are known from the Lower Ordovician of Smøla island Norway, the Durness limestone of Scotland and the Middle Ordovician and later rocks in the Girvan and other districts of Britain (STRAND, 1932, DONALD, 1902, '06).

As noted on the previous occasion (1958), the occurrence of *Actinoceras*, *Armenoceras* and *Ormoceras* in the Thailand-Malayan border is a remarkable fact, because the cephalopods from South China, Burma and the Himalaya which were placed in these genera or *Gonioceras* are found to be erraneous references. The presence of actinoceroids in these regions is now a question. In Korea and North China on the other hand the actinoceroids are well represented in the Ordovician fauna. It is known now that the Toufangian fauna of Eastern Asia was connected with the related ones of North America and Arctic regions through Siberia as proven by the followings (BELIAEVSKY et al., 1958):

1. *Actinoceras bigsbyi* in the Llandeilian Krivolutsk formation of the Siberian platform.
2. *Armenoceras holtedahli* from the Siberian platform.
3. *Armenoceras* cfr. *holtedahli* from the Upper Ordovician of Kotelny island, New Siberia.

Armenoceras holtedahli was originally described by STRAND (1933) from the gastropod limestone of the Oslo region, Norway, but as pointed out by TEICHERT (1930) and STRAND, the Upper Ordovician cephalopods of the Baltic region are intimate to those of the Arcto-American ones. The actinoceroids of the Thailand-Malayan border are connecting links in the distribution of the Toufangian terrain of Eastern Asia to Australasia where they are known from Central Australia and Tasmania.

Finally, it is a great interest to see that *Discoceras* which was thrived in the Baltic region in the Middle and Late Ordovician period (STRAND, 1930, SWEET, 1958) is fairly common in Central China. There are some in Yunnan, Burma and the Himalaya which are suggestive of the Himalayan geosyncline for the route of migration of *Discoceras*. Two Malayan species of *Discoceras* are each represented only by a single specimen. Nevertheless, they show the alliance to *Hardmanoceras lobatum* TEICHERT and GLENISTER (1952, 54) from the Upper Canadian of the Desert basin, Australia, or probably a step advanced from that species. It is further noteworthy that *Trocholitoceras idaense* TEICHERT and GLENISTER (1953) from the Upper Canadian of Tasmania bears some characters of *Trocholitoceras* as well as *Discoceras*. Though the material so far obtained are fragmental, the Western Pacific may be the cradle of *Discoceras*, *Hardmanoceras* and *Trocholitoceras*.

Now it is found that Northern Malaya and Peninsular Thailand are located at a cross road in the Ordovician palaeogeography. The JONES' collection which I studied is not a big one, but allowed me to grasp some significant aspects. When I received it, many of them looked poorly preserved, but fortunately their silicification admitted me to isolate them from mother limestone. This painstaking work was taken up and carried out very carefully by my assistant, Mr. Takeo ICHIKAWA to whom I am very much obliged for his survice. I am happy to have the opportunity to study this valuable collection and wish to thank most cordially to Director J. B. ALEXANDER, Messrs E. F. BRADFORD and C. R. JONES of the Geological Survey, Federation of Malaya.

Description of Fossils, Gastropoda

Family Sinuitidae KOKEN

Genus *Sinuitopsis* PERNER, 1903

Sinuitopsis cfr. *kochiriensis* KOBAYASHI, 1943

Plate XXIV, Figures 4 a–b

1933. cfr. *Sinuitopsis kochiriensis* KOBAYASHI, *Jour. Fac. Sci. Imp. Univ. Tokyo, Sect. 2, Vol. 3, Pt. 8*, p. 360, pl. 5, figs. 1–4.

Shell planispiral, composed of about 4 volutions, gradually expanding; umbilicus wide open; whorl subovate or roundly subpentagonal in cross section, depressed, subangulate on lateral sides at about one-fourth from suture where it is broadest; dorsal wall somewhat roof-shaped, but well rounded on top; surface marked by fairly strong radial ribs which are swinging back from the angulation to form V-shaped sinuation on periphery; slit-band absent.

A solitary specimen (No. 11) is 9.5 mm. in diameter where the last whorl is 5. 3 mm. high and 4.2 mm. broad.

This species cannot be included in *Owenella*, because the whorl is much broader, umbilicus narrower and radial striae are fine and numerous in that genus. In the typical forms of *Sinuitopis* the whorl is more compressed laterally. *S. neglecta* PERNER, 1903, from the Ordovician of Bohemia is the type species of *Sinuitopsis*. It differs from this species in the well rounded whorl and very fine ornamentation. *S. nodosa* PERNER, 1903, is another Bohemian species to which these distinctions are also applicable. In addition, it has constrictions which are unusual for the genus. *S. congruens* REED, 1918, from the Balclatchie of Girvan, Scotland, is different from this species in the rounded umbilical edge, U-shaped sinus and more slender surface ornements.

In my opinion this species is most closely related to *S. kochiriensis* from the Chikunsan shale of South Korea, although the specific identification is hesitated. The lateral angulation is found in that species closer to the periphery. As the result the dorsal wall looks nearly flat, instead of roof-shaped in this species. Beside the ribs it has fine threads, but such fine sculptures are absent in this species, if not unpreserved on the specimen. A better material, when uncovered, will enable one to erect a new species for the Malayan form.

Occurrence :—Loc. 42 (Specimen No. 11).

Family Pleurotomaridae D'ORBIGNY

Genus *Hormotoma* SALTER

Hormotoma spp. indt.

Plate XXV, Figures 6, 7a–b

There are some imperfect specimens which are tentatively referred to *Hormotoma*. One No. 22 has an obtuse angulation near the midheight of the whorl. The shoulder plane above it is flat or slightly concave, while the wall is subvertical and rounded below the angulation.

The specimen No. 21, on the contrary, has no angulation, but the whorl surface consists of a broad nearly flat upper part and a narrow rounded lower part. The former is longer than twice the latter part. Compared to the preceding form, this spire appears to be composed of more numerous volutions.

The specimens Nos. 19 and 20 are more similar to the specimen No. 21 than the one No. 22 in the lack of angulation, but these whorls are well rounded and

most expanded near the middle height. No aperture is preserved in these specimens.

Occurrence:—Loc. 34 (Specimens 19–21) and Loc. 31 (Specimen 22).

Family Euomphalidae DE KONINCK

Genus *Helicotoma* SALTER, 1859

Helicotoma jonesi KOBAYARHI, new species

Plate I, Figure 5; Plate XXVI, Figures 5 a–b; Plate XXVII, Figures 9 a–c; Text-figs. 3 b, e.

Description:—Shell discoidal; spire composed of 4 or 5 volutions, slightly sunken below the level of the carina of the last whorl and expanding fairly rapidly; whorl subquadrate in cross section; upper wall gently inclined inward from shoulder but becomes steep just before contact with the preceding whorl; suture running one-third to a half of height of inner whorl below the shoulder; outer wall moderately convex and meets with well rounded basal wall without angulation; carina increases its prominence through growth; umbilicus broad, open and deep.

Observation:—The specimen No. 10 is 17 mm. in diameter where the last whorl is about one-third as wide as the diameter, but its upper wall inclusive of the carina is no more than one-third of the diameter. The specimen No. 18 which is the holotype is about the same as the preceding in size. This shows the section of the whorl. The surface sculptures are obscure in these specimens, but by cross light growth lines appear to form V-shaped sinus and a little notched at the carina.

The specimen No. 7 which is 5 mm. in diameter was procured from the same locality with the specimen No. 10 and is considered probably an immature form of this species. The last whorl occupies one-third the diameter in the apical view, but broader in the basal view. The spire is scarcely sunken. The whorl section is subquadrate, but well rounded on the basal side. The umbilicus is a little narrower than one-third the diameter of the shell and very deep.

The specimen No. 6 which is laterally compressed is 16.3 mm. in diameter where the last whorl is 6 mm. Its spire consists of more than 3 volutions.

Comparison:—This species is closely allied to *Raphistoma sinensis* FRECH, 1895, which is widely distributed in the middle and lower Yangtze valley, Central China. It was first described from Lunshan near Nangking, Prov. Kiangsu, but found later more common in Prov. Hupeh as repeatedly described by FRECH (1911), YABE and HAYASAKA (1920) and GRABAU (1922). Since the last author placed it in *Eccyliopterus*, this reference is generally accepted by Chinese geologists and it is known to be a leading member of the Neichiashan fauna.

R. sinensis has never been described in detail. However, insofar as can be judged from their illustrations, it is distinct from *Helicotoma jonesi*, because the spire is more depressed, the upper wall of the whorl has greater inclination and the last whorl is usually narrower than one-third the diameter of the shell. The whorl section is best shown by GRABAU's specimen which is not so triangular as supposed by FRECH and more similar to the section of this species.

Eccyliopterus louderbacki ENDO, 1932, from the Hanchung basin, Central China, is another ally to this species, but has the spire more roundly expanding. In the rate of expansion *jonesi* is intermediate between *sinensis* and *louderbacki*. The upper wall of the whorl is more steeply slant in *louderbacki* than in *jonesi*.

The whorl of *louderbacki* is trigonally ovate and its spire well sunken as in *sinensis*. *Eccyliopterus shirakii* KOBAYASHI, 1934, from the Tsuibon limestone of South Korea is less similar to this species, because not only these distinctions apply to *shirakii*, but also because there is an angulation on the basal wall of *shirakii*.

The spire is scarcely sunken and the whorl more quadrate in *R.* cfr. *sinensis* by GORTANI, (1934) from Caracorum. *Raphistoma schmidti* KOKEN (in KOKEN-PERNER, 1925) from the *Orthocerenkalk* of Norway is similar to this species, but this shell again has the flat apical side.

None of the above species indicates loose coiling of the spire as diagnostic of *Eccyliopterus* RÉMELÉ, 1888, which is synonymized with *Ecculiomphalus* PORTLOCK, 1843, by KNIGHT (in SHIMER and SHROCK 1949).

The present species has the sunken spire, but the sinking is very slight. The whorl looks quadrate rather than trigonal in section and has a marginal carina. Though rather indistinct, growth lines appear to make a weak selenizone on the carina. Although the spire is commonly a little protruded, such a form as *jonesi* is plausible to place in *Helicotoma* rather than *Eccyliopterus*.

Occurrence :—Loc. 30 (Specimen No. 6), Loc. 31 (Specimens Nos. 7 and 10) and Loc. 34 (Specimen No. 18).

Helicotoma (?) *costata* KOBAYASHI, new species

Plate XXV, Figures 1 a–c; Text-fig. 3 d.

Description :—Shell discoidal with spire in a level and slowly enlarging; whorl subquadrate in section; upper wall a little convex and limited by an obtuse angulation on each side; inner wall steeply slant from the angulation; peripheral band on upper wall indistinct and narrow, if present; outer and lower walls well rounded and marked by relatively coarse, numerous ridges which are swinging back on outer wall as they ascend; umbilicus broad and open.

Comparison :—Specimen No. 9 is, though imperfect, quite distinct from *H. jonesi* in the slow coiling and other features. Unfortunately, however, growth lines are ill-preserved and the peripheral band or selenizone is obscure on the upper wall. Nevertheless, this species is similar to *Helicotoma ichimurai* KOBAYASHI, 1931, from the Shorin formation of North Korea, although the rate of expansion of the whorl is a little greater and the umbilicus relatively small in that species. The coarse ridges on the outer and basal walls represent a feature very rare in *Helicotoma*.

This species is allied also to *Raphistoma* cfr. *sinensis* by GORTANI (1934), but his form is coiling more rapidly and the top is literally horizontal.

The specimen is 30 mm. in diameter where the last whorl is 8 mm. broad.

Occurrence :—Loc. 30 (Specimen No. 9).

Genus *Palaeomphalus* KOKEN, 1925

Palaeomphalus giganteus KOBAYASHI, new species

Plate XXV, Figures 2 a–c, 3 a–c; Plate XXVI, Figures 3 a–c; Text-fig. 3 a.

Description :—Shell somewhat lenticular with apical angle of about 120 degrees; spire composed of 7 or 8 volutions which are expanding gradually; shoulder increasing its prominence through growth to form terraces; cross section of whorl subquadrate; upper wall gently slant and forms an acute angle with lateral wall, but the inclination of the former decreases till at length the wall of the

last whorl becomes horizontal; lateral and basal walls well rounded and gradually bent up into umbilical side; umbilicus half as wide as shell-diameter and largely open; suture running shortly below shoulder; growth lines deeply sinuate and protruded into shallow slit which yields a narrow band along periphery of upper wall; stout ribs appear on basal side of last whorl.

Observation :— This species is represented by three specimens. The largest one, No. 14, which is the holotype is, if complete, more than 65 mm. in diameter and probably as high as 35 mm. The shoulder angle of the last whorl is distinctly produced in the grown stage. Rugose ribs are well marked on this whorl from the lower half of the outer wall to its umbilical wall. There is no angulation on the basal side of this whorl, but the umbilical angulation is known to be distinct in the ealier whorls. The umbilicus is open as far as it is embraced by last four volutions.

A small specimen No. 18 is compressed laterally, its major diameter being 28 mm. and its minor one 24 mm., if complete. The spire is composed of 6 volutions. The umbilical angle is very distinct; the umbilicus a little narrower than a half of the shell-diameter and its apical part closed. Some revolving ribs are seen on the basal wall of last whorl near the umbilicus. Thus these specimens are fairly different in the basal view and the spire appears to coil more slowly in the second than the first specimen.

The third specimen is imperfect, but it is important to see its being an intermediate form between the above two specimens. Namely, in the mode of coiling and other features in the apical and lateral views it agrees with the first specimen, although the umbilical angulation is as strong as that of the second specimen.

Comparison :—An immature form like the second specimen looks similar to *Ophileta* in the apical view, but the spire is higher and the umbilicus much broader in *Ophileta*, because of the slow revolving of the spire. As the general outline is lenticular and the spire coils with moderate rate of expansion, this species somewhat resembles *Liospira*, but in this species the spire is stepping down through distinct shoulders and the calcareous deposit is not well developed in the umbilicus.

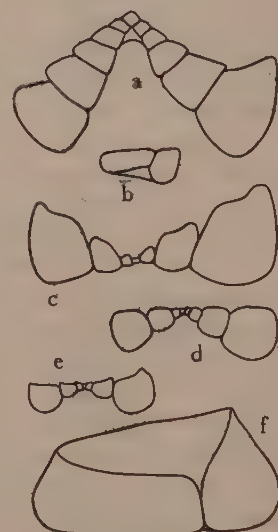

Fig. 3. Diagrammatic sections and side views of some gastropods.
a. *Palaeomphalus giganteus*, (×0.5)
b. *Helicotoma jonesi*, immature, (×2).
c. *Malayaspira rugosa*, (×1).
d. *Helicotoma* (?) *costata*, (×3/4).
e. *Helicotoma jonesi*, mature, (×1).
f. *Lesueurilla zonata*, (×3/4).

Among the Baltic gastropods *Raphistoma scalitoides* KOKEN and *R. qualterium* WAHLENBERG, both from the *Vaginatenkalk* (KOKEN-PERNER, 1925) reveal some similarities with this species, but *R. scalitoides* has the taller whorl and narrower umbilicus and *R. qualterium* possesses the spire lower and non-terraced.

Palaeomphalus keizanensis (KOBAYASHI), 1958, from the Tsuibon limestone of South Korea is the nearest in the Asiatic fauna, but it can be easily distinguished from this species by the more rapid growth of the whorl, greater developement of the shoulder and the smaller umbilicus. KNIGHT (in SHIMER and SHROCK,

1949) is of opinion that *Palaeomphalus* is congeneric with *Helicotoma* SALTER, but there are some differences in the peripheral carination and other features. The peripheral band of this species is flat except for the final stage when the shoulder angle becomes a salient keel as typically seen in *Helicotoma*. The rugose sculpture in this stage is a very distinctive characteristic of this species.

Occurrence :—Loc. 34 (Specimens Nos. 14, 16, 17).

Genus *Lesueurilla* KOKEN, 1898

Lesueurilla zonata KOBAYASHI, new species

Plate XXIV, Figures 6 a–d; Text-fig. 3 f.

Description :—Shell discoidal, with horizontal base; spire composed of some 4 volutions, profoundly depressed; whorl rapidly expanding; its section much higher than broad, subtrigonal and somewhat protruded up, forming a salient keel which is sharply truncated and flat on top; inner wall steeply slant from keel with distinct concavity and in contact with the preceding whorl at two-thirds of its height; outer wall similarly inclined as the inner wall, but straight or more or less convex and gradually rounded toward flat base; elevated and depressed bands of unequal breadth alternating on outer wall, sharply edged or even ridged and ornamentated with fine lines parallel to the bands; these lines and bands arcuate and most protruded forward at about one-third of whorl height; inner wall marked with very fine diagonal lines of growth which are receding as much as they ascend; thus they form Vs with growth lines on outer wall, apparently in addition to shallow sinuation on the carina.

Comparison :—This species is represented by a specimen No. 7 which is 44 mm. in diameter. The last whorl is 15 mm. broad and 21 mm. high.

In the general outline it resembles *Maclurites*, but can easily be distinguished from that genus by the presence of carination. Insofar as I am aware, *Maclurea helix* EICHWALD and *M. dilatata* KOKEN from the *Vaginatenkalk* which were later referred to *Lesueurilla* by PERNER (1925), agree best with this species in the flat base of the spire, its rate of expansion, tall whorl and most other features, but their inner wall does not show such remarkable concavity, as seen in this species. *Maclurea infundibulum* KOKEN from the *Unterer grauer Orthocerenkalk* (KOKEN-PERNER, 1925) which is the type of *Lesueurilla*, and many other species of the genus have the cancave umbilicus. Their whorls are sometimes tending to be detached from one another, although *Lesueurilla* is not so far advanced as *Eccyliomphalus* or *Ecculiopterus* along the trend of loose coiling.

Lecanospira biconcava ULRICH and BRIDGE (in BRIDGE, 1930) has the umbilicus slightly concave. The concavity of the umbilicus is stronger, while the spire is scarcely sunken from the level of the last whorl in *Ophileta alturensis* SARDESON, 1896, which was referred to *Lecanospira* by ULRICH and BRIDGE. In the typical forms of *Lecanospira*, however, the spire is depressed, the base flat and the whorl subtrigonal in cross section and keeled on the top. *Ophileta compacta* SALTER (in KNIGHT, 1941) which is the type of the genus is especially allied to this species in the subtriangular whorl section with the concave inner wall. In *Lecanospira*, however, the spire consists of more numerous volutions which are very slowly expanding. In my opinion it is probable that such a form as *L. zonata* can be derived from *Lecanospira*, but the banded structure on the outer wall of the last whorl is the speciality of this species which I could not find either in *Lecanospira* or in *Lesueurilla*.

Occurrence :—Loc. 31 (Specimen No. 7).

Lesueurilla (?) sp. indt.

Plate XXVI, Figures 6 a–b

This species looks to be allied to the preceding in the descendant spire, high subtrigonal whorl section and distinctly concave inner wall. The whorl is higher in this than that species and angulated on the top but scarcely protruded. The basal wall is well rounded; basal umbilicus concave to some degrees. The spire is composed of about 5 volutions. Ribs on the outer wall are narrower than their interspaces and running diagonally on the outer wall.

This species resembles *Maclurites niuhsintaiensis* (KOBAYASHI), 1930, or *M. nitida* by ENDO, 1932, from the Toufangian of South Manchuria, in the high whorl and strong angulation, but the whorl is enlarging more rapidly, its base flat, the inner wall convex and the apical umbilicus much narrower in *niuhsintaiensis*.

The specimen No. 13 is 32 mm. across and about 23 mm. high. Although it is poorly preserved to make a precise comparison, it is very similar to the preceding species in many characteristics. The whorl is, however, not distinctly carinated in this species.

Occurrence :—Loc. 34 (Specimen No. 13).

Genus *Malayaspira* KOBAYASHI, 1958

1958. *Malayaspira* KOBAYASHI, *Japan. Jour. Geol. Geogr. Vol. 29*, p. 226.

Diagnosis :—Shell discoidal with flat base; umbilicus wide open; spire sunken as far as basal walls of whorls become almost in the same plane; whorl expanding gradually; its cross section subquadrate; top wall narrow, flat or concave and carinate along periphery; three other walls more or less convex; growth striae rugose, sinuated on top and produced behind into shallow notches at carina.

Type-species :—*Malayaspira rugosa* KOBAYASHI, 1958.

Remark :—This genus resembles *Lecanospira* in the depressed spire and flat base, but *Lecanospira* can easily be distinguished from this genus by the subtrigonal whorl section with an acute crest and more numerous whorls. In the rate of expansion and cross section of the whorl this genus is closer to *Helicotoma* than *Lecanospira*. In *Helicotoma*, however, the spire is often elevated and never so much depressed as in this genus. The upper wall is broad and in contact with the outer wall of the preceding whorl and the peripheral carination is more prominent in *Helicotoma* than in this genus. In this genus the top wall is very narrow and the inner wall which is slightly convex is contact with the outer wall of the preceding whorl at about its middle height.

It is remarkable that surface sculptures are stronger on the outer and basal walls than on the others in the type-species. In the angulation between the upper and inner walls, this resembles *Ophiletina*, but the whorl section is hexagonal, the outer wall bisected by a median carina and the last whorl becomes out of contact in the typical forms of *Ophiletina*.

Distribution :—Ordovician; Southeastern Asia.

Malayaspira rugosa KOBAYASHI, 1958

Plate XXIV, Figures 1 a–c, 2, 3 a–c; Text-fig. 3 c.

1958. *Malayaspira rugosa* KOBAYASHI, *Japan. Jour. Geol. Geogr. Vol. 29*, p. 227, pl. 18, figs. 1a–c.

Four specimens of this species are contained in JONES' collection. The largest (No. 8) of them measures about 41 mm. in diameter. It is composed of 5 volutions and the last whorl 15.2 mm. broad, but the original breadth may be a little different because the whorl is destructed.

The specimen No. 4 is better preserved, but a little smaller than the preceding. Its inner whorls are unpreserved, but the ultimate and penultimate ones show the rapid descendance of the spire, the gradual expansion of the whorl and other features.

The whorl is subquadrate in cross section, higher than wide and somewhat narrowing upward. Growth lines bear rugose appearance on the outer and basal sides, slightly convex to the adapical side on the basal wall, and subvertical in the lower half of the outer wall, but swinging back in the upper half, they form V-shaped sinuation on the summit carina where they appear slightly notched behind and strengthened in form of a chain of nodes. The upper wall is gently slant inward with weak concavity and meet with the subvertical inner wall by an obtuse angulation. The growth lines become less oblique on the inner than the upper wall.

The specimen No. 2 is somewhat compressed laterally and the spire less depressed than the others, but otherwise it is diagnostic and the surface sculptures are especially well preserved and somewhat depressed in basal view.

Specimen No. 5 is a small, ill-preserved specimen which is laterally compressed. The sunken spire suggests that the specimen No. 15 is probably a poor specimen of this species.

Occurrence : — Loc. 30 (Specimens Nos. 4 and 6), Loc. 31 (Specimen No. 8), Loc. 32 (Specimen No. 5) and Loc. 34 (Specimens Nos. 2 and 15).

Malayaspira (?) sp. indt.

Plate XXV, Figure 4.

This form is represented by an incomplete shell which appears to be the basal wall similar to that of *Malayaspira rugosa*, but more convex. The inner whorls are distinctly depressed below the outer and their suture is profound. Surface sculptures are much finer than those of *rugosa*. The shell is 45 mm. in diameter; last whorl as wide as 14 mm.

Occurrence :—Loc. 34 (Specimen No. 13).

Genus *Lytospira* KOKEN, 1890

Lytospira rectangularis KOBAYASHI, new species

Plate XXV, Figures 5 a–c

Description :—Shell horn-shaped with no plane of symmetry. In lateral view, however, the horn looks to be composed of a transverse and longitudinal part which are disposed almost rectangularly, although the former part transmits into the latter gradually without forming an angle; shell expanding more rapidly in the former than in the latter part; cross section trigonally ovate; convex side a little narrower than flanks, sharply defined by angulation and bipartate by a low obtuse median ridge. Apertural margin appears profoundly sinuated on this side. Nucleus unpreserved.

Comparison :—This species is very similar to *Lytospira norvegica* KOKEN from the *Ogygiaschiefer* of Oslo (KOKEN-PERNER, 1925). It is, however, very unlikely that this shell is sinuated on the upper edge as seen in *Euomphalus angelini*

LINDSTRÖM, 1884, which is the type-species of *Lytospira* KOKEN.
Occurrence :—Loc. 5 (Specimen No. 37).

Nautiloidea

Family Endoceratidae HYATT, 1883

Genus *Endoceras* HALL, 1844

Endoceras (?) sp. indt.

Plate XXVI, Figures 4 a–b

A siphuncle 98 mm. long, longiconic, gradually tapering with the rate of 1 mm. in 7 to 8 mm and very slightly arcuate; its cross section subcircular, but a little depressed dorso-ventrally and somewhat flattened on convex side; endocone subcentral, longiconic and subcircular, but more or less flattened on the convex side of the siphuncle; endosiphuncle crescentic in section with convexity on concave side of the siphuncle and located a little close to this side, its breadth being narrower than one third as wide as the siphuncle; surface annulated; annulations and constrictions seemingly straight, equally weak and about same in length and running apparently all around the siphuncle; 4 annuli and 3 intervals distributed in the length of 12 to 14 mm.

The flattening of the endocone and the convexity of the endosiphuncular section suggest that the siphuncle is exogastric. If this orientation is correct, it must be a member of the Bassleroceratidae, instead of the Endoceratidae or Cyrtendoceratidae, and there is no species known from Eastern Asia which is comparable to this species. The curvature of the siphuncle is, however, neither strong nor quite regular. It is probably due to the twisting of the siphuncle at least to some degrees, which must be the secondary modification. The flattening of the siphuncle does not match with its curvature exactly and it suggests that the siphuncle was possibly located marginally. The surface of the siphuncle is not well preserved and it is indeterminable either holo- or ortho-choanitic.

The dorso-ventral diameter of the siphuncle is 6.5 mm. at the adapical end, but enlarges to 16.5 mm. in the length of 7.5 cm. From this siphuncle it is inferred that the conch is fairly large and rapidly expanding and has numerous short camerae. In view of the large siphuncle, its rapid expansion and developed internal structure, it looks to be more likely an endoceroid rather than an *Avaoceras* or any other genus of the Bassleroceratidae.

Occurrence :—Loc. 31 (Specimen No. 28).

Endoceroid, gen. and sp. indt.

Plate XXVII, Figures 2 a–b

A fragmentary siphuncle, about 30 mm. long, elliptical in cross section which is 12.5 mm. by 10.5 mm. at the adapical end whereas the longer or lateral diameter is 16.5 mm. at the other end. The endosiphuncle is subcentral, crescentic in cross section, a little broader than one third the lateral diameter at the narrow end; surface ill-preserved, but apparently non-annulated.

This siphuncle resembles the preceding in the rate of expansion and the section of the siphuncle, but its preservation is too poor to say their relationship.

Occurrence :—Loc. 28 (Specimen No. 27).

Family Ormoceratidae SAEMANN, 1852

Genus *Ormoceras* STOKES, 1852

Ormoceras langkawiense KOBAYASHI, new species

Plate XXVII, Figures 3 a–b. 4 a–b and 5 a–b

1958. *Stereoplasmoceras* (?) sp. indt. KOBAYASHI, *Japan. Jour. Geol. Geogr. Vol. 29*, p. 227.

Specimen No. 25 is the holotype of this species. It is 20 mm. in length in which 10 camerae are distributed. On the polished section through the siphuncle it is seen that the siphuncle is subcentral and 3 mm broad in the adoral part where the conch is 17 mm. broad. The diameter of the siphuncle is nearly the same at the other end of the specimen. The septum is gently convex to the adapical side as much as a septal interval and recurving at the neck to describe a small loop. There the siphuncle is contracted to one-third the diameter of the nummulus. The neck ring is small and nearly circular in longitudinal section. The episeptal deposit is thickened proximally.

In BURAVAS' collection there were two specimens which are thought to belong to this species. On the previous occasion it was suggested to be an ormoceroid, but it was called *Stereoplasmoceras* (?) sp. because no siphuncular structure was known. The larger one of the two specimens was already described in some detail. The smaller one is about 30 mm. long. Its diameter is 7.5 mm. at the adaptical end where it is circular. The siphuncle is located near the center and about one fifth as wide as the conch. Eight septa and seven camerae are distributed in the length of 8 mm. in the middle part of the specimen.

Occurrence :—Loc. 30 (Specimen No. 25); Kangar, Perlis (BURAVAS collection).

Ormoceras sp. indt.

Plate XXVII, Figures 1 a–b

Specimen No. 24 is a phragmacone of 37 mm. in length in which 8 camerae are countable. The conch is apparently cylindrical and nearly circular; siphuncle narrow and central. In the polished longitudinal section the former is 30 mm. in diameter where the latter is 8 mm at the middle of the siphuncular segment and 3.3 mm. at the septal neck. It is seen on the section that the septal depth corresponds to about twice the septal interval, the septum is regularly convex and describes a small semi-ellipse at the neck; connecting ring semi-circular in section; neck ring small; episeptal and hyposeptal deposit well developed and meeting each other in early camerae, forming a pseudoseptum.

Occurrence :—Loc. 5 (Specimen No. 24).

Family Armenoceratidae FOERSTE and TEICHERT, 1930

Genus *Armenoceras* FOERSTE, 1924

Armenoceras chediforme KOBAYASHI, 1958

Plate XXVII, Figures 6, 7 a–b and 8

1958. *Armenoceras chediforme* KOBAYASHI, *Japan. Jour. Geol. Geogr. Vol. 29*, pp. 229, pl. 19, figs. 2 a–b, text-fig. 3.

There are three specimens of *Armenoceras* from loc. 5 which are thought to belong to this species. Specimen No. 23 is a part of a conch of about 7 cm. in length on which 9 camerae are countable in the length of 44 mm. The siphuncle appears about half as wide as the conch and to be located probably near the

center, although the excentricity cannot be exactly determined. In the polished section it is measured that the breadth of the siphuncle is 12.5 mm. and 23.5 mm. respectively at a septal neck and segment. There the central canal is 5.5 mm. broad. The septal interval is about 5 mm. on an average and the septal depth corresponds roughly to two intervals. The septum is inserted between two nummuli. The septal neck of about 2 mm. is adnated to the septum proper. The episeptal deposit is fairly well developed.

The specimen No. 30 is a siphuncle of 34 mm. in length in which 6 and a half nummuli are distributed. The expanded part of the siphuncle is eroded out, but the original breadth is estimated about 25 mm. The septal adnation is quite similar to that of the preceding specimen. The central canal is excentric, subcylindrical and about 5 mm. in diameter; radial canals nearly horizontal on the dosral side, but commonly bent back to some extent on the other side.

The specimen No. 31 is a siphuncle about 28 mm. in breadth and 37 mm. in length in which 7 nummuli are countable. Its central canal appears more excentric than the preceding and located at about one-third from the dorsal side. The high excentricity of the canal suggests its being the dorso-ventral section. The septum forms an obtuse angle at its adnate portion. Though less significant, such angulation is seen also at a few septa of the specimen No. 30.

The two siphuncles are similar to that of the first specimen in the size of the siphuncle and septal distance which is 4.5 to 5 mm. Their septa are similarly adnated at the necks; radial canals all nearly horizontal. These features are also seen in the holotype from Thung Song, Thailand. The specimen No. 23 shows fairly good agreement with the type specimen in the relative size and position of the siphuncle to the conch. Because the outline of the siphuncle and the curvature of the septa are irregular in the type specimen, it is highly probable that its siphuncle was curved by secondery deformation.

Occurrence: —Loc. 5 (Specimens Nos. 30, 31 and 32) and Thung Song, Thailand.

Family Trocholitidae CHAPMAN, 1857

This family includes *Trocholites* CONRAD, 1838, *Discoceras* BARRANDE, 1867, *Litoceras* HYATT, 1883, *Trocholitoceras* HYATT, 1894, *Curtoceras*, *Arkoceras*, *Jasperoceras* and *Wichitoceras* by ULRICH, FOERSTE, MILLER and FURNISH, 1942 and *Hardmanoceras* TEICHERT and GLENISTER, 1952, all from the Ordovician and a Gotlandian *Graftoceras* FOERSTE, 1925. *Cyclolituites* RÉMELÉ, 1886, was referred to this family by ULRICH et al. (1942), but now in the Lituitidae NOETLING (FLOWER and KUMMEL, 1950). STRAND (1933) pointed out that *Schroedoceras* HYATT, 1894, is congeneric with *Discoceras*, the opinion being now generally accepted. SHIMIZU and OBATA (1935) proposed *Eurasiatoceras* for *Discoceras eurasiaticum* FRECH. According to them "This genus is quite distinct from *Discoceras* by having much narrower, more crowded ribs which are covered by concentric striae on some part of the shell." This distinction is, however, neither very significant nor important enough to discriminate *Eurasiatoceras* from *Discoceras*, although the name may serve in future for segregation of certain oriental or Pacific forms from *Discoceras* s. l.

Genus *Discoceras* BARRANDE, 1867

Type-species: *Clymenia antiquissima* EICHWALD, 1840

As shown by STRAND (1930), SWEET (1958) and others, the genus most flour-

ished in the Baltic region in the Middle and Late Ordovician period. Beside the type-species there occur some 15 species and 1 subspecies, namely, *annulatus* SAEMAN, 1852, *rarospira* EICHWALD, 1860, *arcuatus* LOSSEN, 1860, *seamanni* HYATT, 1894, *tubulatum* HYATT, 1894, *hyatti* STRAND, 1930, *roemeri* STRAND, 1930, *gubkovense* BALASCHOV, 1953, *ievesense* BALASCHOV, 1953, *tammikuense* BALASCHOV, 1953, *vasalemmense* BALASCHOV, 1953, *wesenbergense* BALASCHOV, 1953, *boreale* SWEET, 1953, *boreale amplicameratum* SWEET, 1958, *depressum* SWEET, 1958, and *fleischeri* SWEET, 1958.

Discoceras canadense WHITEAVES, 1897, and allied forms are reported to occur in the Upper Ordovician of Lake Winnipeg, Canada, Baffin island and Sutton island of the Canadian Arctic archipelago (TEICHERT, 1937, MILLER and YOUNGQUIST, 1947, MILLER et al. 1954), among which *Discoceras* (?) sp. by MILLER et al. from Silliman's Fossil Mount, Baffin island is excluded from the genus by SWEET.

SHIMIZU and OBATA (1935) has once suggested *Discoceras* for *Plectoceras ohtakai* ENDO, 1932, from South Manchuria. It is represented by an external mould which is characterised by the gradually enlarging spire, large umbilical perforation, well defined rib-like folds and the remarkable dorso-lateral angulation of whorls. SHIMIZU and OBATA emphasized the last two features for the points of disagreement with *Plectoceras*, but such angulation of whorls and strong oblique folds are present in *Nautilus jason* BILLINGS which is the type-species of *Plectoceras*. Because the whorl section is imperfectly known and the siphuncular position unknown, it is indeterminable whether it belongs to the Trocholitidae, or whether does it to the Plectoceratidae, but it is not the less probable to be a *Plectoceras* than a *Discoceras*.

Discoceras is not rare in Prov. Hupeh, Central China. FRECH (1911) has described two species, *Discoceras eurasiaticum* (Taf. 1, Fig. 1 a–b, non 2 a–b) and *D. verbeeki*. The whorl section is more quadrate in the former, but more rounded in the latter. The ribs in these species are similarly bent back to form Vs on the venter, but they are finer and more numerous and become weaker in the latter than in the former. The siphuncle is narrow and marginal on the dorsal side in these species. Beside *D. eurasiaticum*, YABE and HAYASAKA (1920) described *Discoceras* sp. whose whorls are, like *D. verbeeki*, broad and fairly rounded in cross section and the siphuncle is again marginal (pl, 27, fig. 6). It is said to disagree with the two species in the relatively wide umbilicus. YABE and HAYASAKA's specimen of *eurasiaticum* clearly shows that the ribs appear narrow ridges, not imbricated and separated from one another by broader intervals than the ribs. YÜ (1930) illustrated two specimens of *eurasiaticum* which were procured from the upper part of the Middle Ordovician Neichiashan formation. In the exfoliated part of his specimen in fig. 5, pl. 9 it is recognizable that the septal sutures intercross the ribs. Thus there are three species of *Discoceras* in Central China. It can, however, hardly be overlooked that the siphuncle is usually marginal or almost marginal in the Hupeh forms, instead of submarginal in the typical *Discoceras*. Their ribs are never imbricated.

When I described *Trocholites ammonoides* from South Korea (1934), I noticed that *Trocholites juliformis* SALTER in REED (1921) from the Himalaya, *T.* cfr. *remelei* SCHROEDER by REED (1906) from Burma, *T. yunnanesis* REED and *T.* cfr. *macromphalus* SCHROEDER by REED (1917) from Yunnan in South China look similar to *Discoceras* than *Trocholites*. Lately SWEET (1958) expressed the opinion

that the first and the third species of them may properly referred to *Discoceras*. *T. yunnanensis* having a marginal siphuncle is a close relative to *eurasiaticum*. It is noted further that SHIMIZU and OBATA (1936) suggested the possibility of REED's *Tarphyceras* (?) sp. from Yunnan to be a *Schroedoceras*, i. e. a *Discoceras*, but its whorl is too much compressed laterally for *Discoceras*. These specimens from South and Southeastern Asia are unfortunately not well preserved. Nevertheless, it is of great interest that they reveal important links in the chain of distribution of the genus between the Baltic region and Eastern Asia.

Finally, *Discoceras* (?) sp. from the Lower Ordovician of Bendigo, Victoria, Australia (THOMAS and TEICHERT, 1947) is the oldest of the genus, if correctly referred to it, but it needs a further confirmation with a better material. *Trocholitoceras idaense* TEICHERT and GLENISTER (1953) from Tasmania is according to the authors, allied to *Trocholitoceras* as well as *Discoceras*. The authors instituted *Hardmanoceras* on their *H. lobatum* from Desert basin, Western Australia. This genus agrees with *Discoceras* in the subrectangular whorl section, subdorsal position of the siphuncle and some other characters. It is the monotypic species which is especially interesting to see the agreement with the Malayan forms of *Discoceras* in "Ribs prominent on the flanks, becoming faint as they cross the venter forming a deep V-shaped lobe." The effacement of the ribs on the venter is more advanced in the Malayan than the Australian species.

In looking through these occurrences it is found that the Western Pacific must have been a center of distribution of *Discoceras* and its close allies. On the Australian side they are found in the Lower and Middle Ordovician rocks. They flourished more on the Asiatic side in the Middle Ordovician period. It is probable that the Himalayan geosyncline was the Eurasiatic route of migration for *Discoceras*. In Northern Europe *Discoceras* attained its zenith in the Middle and Late Ordovician period when its distribution was expanded as far as the Arctic seas.

Discoceras (*Hardmanoceras* ?) *chrysanthimum* KOBAYASHI, new species

Plate XXVI, Figures 1 a–b

Description :—Shell discoidal, composed of about 5 volutions, slowly expanding; whorl subquadrate in cross section and slightly impressed on dorsal side; outer wall a little inflated. subangulated on the borders with gently and regularly convex flanks; siphuncle subdorsal at least in last whorl; body whorl occupies more than a half volution; flanks marked with strong radial ribs which are somewhat thickened distally and a little bent forward near the ventral wall; they form rectangular sinuses with their counters on ventral wall, but they are not so prominent there as on flanks.

Measurement and observation :—The type specimen No. 3 is composed of 5 volutions and 41 mm. in diameter. The aperture is unpreserved, but it is certain that at least a little more than a half of the ultimate whorl belongs to the body chamber. The last septum is seen at the point marked by s in figs. a–b. There the whorl is 8.5 mm. high and 12 mm. wide. The septum is strongly concave, its concavity corresponding to about a half of the whorl height. Although the septal suture is not exposed on the specimen, it is evident that the suture intercrosses the radial rib.

The penultimate whorl, the third and fourth whorl counted inwardly measure 24.5 mm., 15 mm. and 8.5 mm. in diameter respectively. The radial ribs

are countable 16 and 14 on a half of the second and third whorl respectively. On the natural section the location of the siphuncle can be recognized to be very close to the dorsal margin of the last whorl, although there is no sagittal section through the siphuncle. The camerate portion is largely recrystallized, while the body chamber is mostly filled with calcareous dirt.

Comparison :—Although the internal structure is not well known, it is certain that this form belongs to *Discoceras* s. l. because of the slow coiling of the conch, subquadrate whorl section, subdorsal siphuncle and mode of ornamentation. In the typical *Discoceras* it is said that "Shell surface marked by adapically imbricate lamella." The periodic annulations or ribs are, however, noted to appear in the advanced forms in the Baltic region.

This species agrees better with *Hardmanoceras* than typical *Discoceras*, with regard to the prominent ribs on the flanks which become weak on the venter where they are V-shaped. In *Hardmanoceras* the body whorl is extraordinarily long, occupying one and a quarter of a volution. The body whorl of this species is also possibly very long, because the outer wall of the last whorl near s point suggests the attachment of the still outer whorl.

H. lobatum TEICHERT and GLENISTER (1952) is the monotypic species of *Hardmanoceras* whose whorls look more slowly expanding. It is known on the hypotype of the species that the coiling tends to be released at the last quarter of a volution (TEICHERT and GLENISTER, 1954), but all whorls are in contact not only in this species but also in the succeeding species whose spire is enlarging more rapidly. Although there are some differences, the Malayan forms of *Discoceras*, s. l. are intimate to *H. lobatum* from the upper Canadian of Australia. At the same time it is noted that the distinction of *Hardmanoceras* from *Discoceras* is not quite sharp.

Occurrence :—Loc. 31 (Specimen No. 3).

Discoceras (*Hardmanoceras*?) *laeviventrum* KOBAYASHI, new species

Plate XXVI, Figures 2 a–b

This is represented by a phragmacone, 32.5 mm. in diameter. It is composed of 4 volutions which are expanding a little more rapidly than in the preceding species. If the umbilicus is open, it must be a very small perforation. At the adoral end of the specimen the whorl is 9.5 mm. high and 12 mm. wide. It is subquadrate in cross section, but comparatively more rounded than the section of the preceding species. The dorsal impression of the whorl is shallow. The body chamber is unpreserved. The second and third whorl counted inwardly, are respectively 16.5 mm. and 9 mm. in diameter and possess 14 and 9 ribs on a half volution. They are as strong as those of the preceding species, but become very weak on the last whorl on the venter of which they are completely obsolete. Like the preceding, the siphuncle is located near the dorsal margin at least on the last two whorls of this specimen.

This species is distinguishable from the preceding by the more rapid growth, more rounded whorl section and especially by the evanescence of the ribs which is quite significant, if they are compared in the grown stage. This species is somewhat similar to *Trocholitoceras idaense* TEICHERT and GLENISTER, 1953, from Tasmania, but can easily be distinguished by the more rounded whorl section and the more dorsal position of the siphuncle.

Occurrence :—Loc. 31 (Specimen No. 12).

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T. KOBAYASHI

On Some Ordovician Fossils from Northern Malaya and her Adjacence

Plate XXIV

Explanation of Plate XXIV

Malayaspira rugosa KOBAYASHI .... p. 398

Figures 1a–c. Apical, basal and lateral views of Specimen No. 2. ×2. Loc. 34.

Figure 2, Apical view of Specimen No. 8. ×1.5 Loc. 31.

Figures 3a–c. Apical, lateral and basal views of Specimen No. 4. ×1.5 Loc. 30.

Sinuitopsis cfr. *kochiriensis* KOBAYASHI .... p. 393

Figures 4a–b. Lateral and dorsal views of Specimen No. 11. ×3 Loc. 42.

Helicotoma jonesi KOBAYASHI, new species .... p. 394

Figures 5. Apical view of Specimen No. 10. ×2 Loc. 31.

Lesueurilla zonata KOBAYASHI, new species .... p. 397

Figures 6a–d. Apical, basal and two lateral views of Specimen No. 7. ×1.5 Loc. 31.


1a
1b
1c
2
3a
3b
3c
4a
4b
5
6a
6b
6c
6d

T. Kobayashi

On Some Ordovician Fossils from Northern Malaya and her Adjacence

Plate XXV

Explanation of Plate XXV

Helicotoma (?) *costata* KOBAYASHI, new species .... p. 395

Figures 1a–c. Apical, lateral and basal views of Specimen No. 9. ×1.5 Loc. 30.

Palaeomphalus giganteus KOBAYASHI, new species .... p. 395

Figures 2a–c. Apical, lateral and basal views of Specimen No. 16. ×1.5 Loc. 34.

Figures 3a–c. Lateral, apical and basal views of Specimen No. 14. ×1. Loc. 34.

Malayaspira (?) sp. indt. .... p. 399

Figure 4. Basal view of Specimen No. 13. ×1. Loc. 34.

Lytospira rectangularis KOBAYASHI, new species.. p. 399

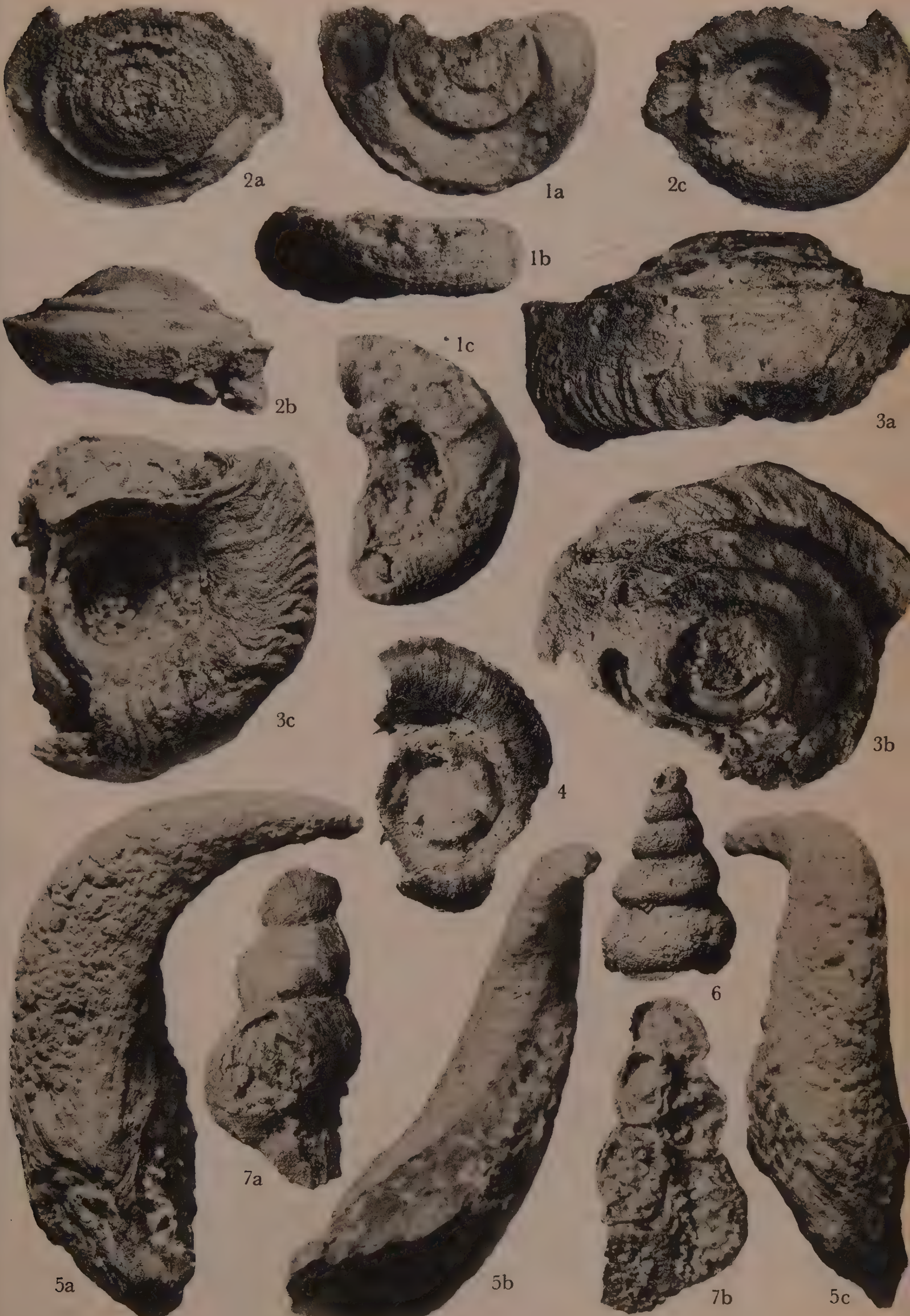
Figures 5a–c. Lateral views of Specimen No. 37. ×1.5 Loc. 5.

Hormotoma a sp. .... p. 393

Figure 6. Lateral view of Specimen No. 21. ×1. Loc. 34.

Hormotoma b sp.. p. 393

Figures 7a–b. Lateral view and natural longitudinal section of Specimen No. 22. ×1. Loc. 34.


2a
1a
2c
1b
1c
2b
3a
3c
3b
4
6
7a
5a
5b
7b
5c

T. KOBAYASHI

On Some Ordovician Fossils from Northern Malaya and her Adjacence

Plate XXVI

Explanation of Plate XXVI

Discoceras (*Hardmanoceras* ?) *chrysanthimum* KOBAYASHI, new species .... p. 404

Figures 1a–b. Two lateral views of Specimen No. 3. ×1.5. Loc. 31.

Discoceras (*Hardmanoceras* ?) *laeviventrum* KOBAYASHI, new species .... p. 405

Figures 2a–b. Lateral and ventral views of Specimen No. 12. ×2. Loc. 31.

Palaeomphalus giganteus KOBAYASHI, new species .... p. 395

Figures 3a–c. Apical, lateral and basal views of Specimen No. 17. ×1. Loc.34.

Endoceras (?) sp. indt. .... p. 400

Figures 4a–b. Two lateral views of a siphuncle. Specimen No. 20. ×1.5. Loc. 31.

Helicotoma jonesi KOBAYASHI, new species .... p. 394

Figures 5a–b. Apical and lateral views of Specimen No. 18. Holotype. ×2. Loc. 34.

Lesueurilla (?) sp. indt. .... p. 398

Figures 6a–b. Basal and lateral views of Specimen No. 13. ×1.5. Loc. 34.


S
1a
S
1b
2a
2b
3a
3b
3c
4a
4b
5a
5b
6a
6b

T. Kobayashi

On Some Ordovician Fossils from Northern Malaya and her Adjacence

Plate XXVII

Explanation of Plate XXVII

Ormoceras sp. indt. .... p. 401

Figure 1a. Eroded surface of Specimen No. 20. ×1. Loc. 5.

Figure 1b. Longitudinal section of the same specimen, ×1.5

Endoceroid, Gen. and Sp. indt. .... p. 400

Figure 2a. Lateral view of a siphuncle. Specimen No. 27. ×1.5. Loc. 28.

Figure 2b. Cross section of the same siphuncle. ×2.

Oromo-eras langkawiense KOBAYASHI, new species .... p. 401

Figure 3a. Eroded surface of Specimen No. 25. Holotype. ×1.5. Loc. 30.

Figure 3b. Same phragmacone. ×2.

Figures 4a–b. Natural longitudinal and cross sections of a specimen from Kangar, near Perlis. ×1.5.

Figures 5a–b. Another specimen from Kangar, Perlis. ×2.

Armenoceras chediforme KOBAYASHI .... p. 401

Figure 6. Longitudinal section of Specimen No. 31. ×1.5. Loc. 5.

Figures 7a–b. Eroded surface and longitudinal section of Specimen No. 30. ×1.5 Loc. 5.

Figure 8. Longitudinal section of Specimen No. 23. ×1.5. Loc.5.

Helicotoma jonesi KOBAYASHI, new species .... p. 394

Figures 9a–c. Lateral, apical and basal views of Specimen No. 7. ×4. Loc. 31.


1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6
7a
7b
8
9a
9b
9c

STUDIES ON THE OSTRACODA FROM JAPAN

V. *Subfamily Cytherinae* DANA, *1852 (emend.)*

By

Tetsuro HANAI

With one Plate

Introduction

When the subfamily Cytherinae is restricted to genera closely related to *Cythere*, the subfamily contains only a small group of Ostracoda, including the genera *Cythere* and *Loxocythere*. More than 1,000 species has been described under the name *Cythere*. However, *Cythere lutea* O.F. MÜLLER, the type species of the genus *Cythere* is so far only the species of this genus which is properly described. Genus *Cythere* s. str. is known from the northern European coast, from the Arctic and North Atlantic and from the Mediterranean Sea, while the genus *Loxocythere* is known from New Zealand and the Mediterranean Sea.

Japanese samples contain two species of the genus *Cythere*, including two new subspecies of *Cythere lutea* O.F. MÜLLER, and a single species of *Loxocythere*.

Genera of the subfamily Cytherinae

The subfamily Cytherinae s. str. is characterized first by the merodont hingement in which the anterior and posterior teeth are dentate, second by the projection of the dorsal margin of the right valve above that of the left along the hinge margin, and third by lack of strong wing-like projections of the carapace. The third character differentiate the cytherids from most of the cytheropterid Ostracoda. Further, in interior view the cytheropterid ala is divided by an inward-projecting ridge into two portions, as is also the case in *Paijenborchella*. This condition does not exist in the cytherid Ostracoda. In the cytheropterid Ostracoda the anterior and posterior hinge elements tend to become knob-like teeth, while the anterior and posterior elements of cytherid hingement are always dentate. The genera *Cythere* s. str. and *Loxocythere* have all of the above mentioned characters and are considered to be good representatives of this subfamily.

Merodont hingement of cytherideid type is quite different from that of cytherid and cytheropterid types in its hinge and flange arrangement. In the subfamily Cytherinae, as in the subfamily Cytheropterinae, the flange is strongly developed and overhangs the actual hingement of the right valve, but does not reach the terminal teeth, so that a furrow is formed between the terminal teeth and the overhanging flange.

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Repository of types

All types are deposited in the collection of the Institute of Geology, Faculty of Science, University of Tokyo. Duplicate paratypes are also deposited in the H.V. HOWE collection, Department of Geology, Louisiana State University, Baton Rouge, Louisiana, U.S.A.

Systematic descriptions

Family Cytheridae BAIRD, 1850

Subfamily Cytherinae DANA, 1852 (emend.)

Genus *Cythere* O.F. MÜLLER, 1785

Type-species: *Cythere lutea* O.F. MÜLLER, 1785

Cythere O. F. MÜLLER auct. part.[1] (O. F. MÜLLER, 1785, pp. 63–67; DESMAREST, 1825, p. 387[2]; BAIRD, 1838, pp. 139–142; CORNUEL, 1846, p. 196; BOSQUET, 1847, p. 356; JONES, 1849, p. 8; BAIRD, 1850, pp. 163–168; BOSQUET, 1852, pp. 49–55; LILLJEBORG, 1853, pp. 164–167; BOSQUET, 1854, pp. 75–79; BORNEMANN, 1855, pp. 361–365; JONES, 1857, p. 23; SARS, 1865, p. 28; BRADY, 1866, p. 371; RICHTER, 1867, p. 226; BRADY, 1868, p. 120; BRADY, 1868, Monograph, pp. 393, 394; REUSS, 1874, pp. 143, 144; BRADY, CROSSKEY and ROBERTSON, 1874, pp. 141, 142; BRADY, 1878, Antwarp, p. 383; BRADY, 1880, p. 62; MARSSON, 1880, p. 38; TERQUEM, 1885, p. 22; JONES, 1885, p. 349; JONES and SHERBORN, 1887, p. 338; DAHL, 1888, p. 605; JONES and SHERBORN, 1889, p. 19; BRADY and NORMAN, 1889, p. 125[3]; LIENENKLAUS, 1894, p. 174; G. W. MÜLLER, 1894, p. 350[4] NAMIAS, 1900, p. 90; LIENENKLAUS, 1900, p. 529; SHARPE, 1909, pp. 419, 420; HIRSCHMANN, 1912, pp. 45, 50[4]; G. W. MÜLLER, 1912, p. 217; SARS, 1925, p. 167; NEVIANI, 1928, p. 57; ALEXANDER, 1929, p. 78).

Monoculus GMELIN auct. part.[1] (GMELIN, 1788, p. 3001).

Cytherina LAMARCK auct. part.[1] (LAMARCK, 1818, p. 125; not SYLVESTER-BRADLEY, 1946, p. 196[3]).

1931 *Cythere* BLAKE, pp. 163–165.
1936 ——— VAN VEEN, p. 41.
1938 ——— KLIE (part.), pp. 163–165.
1942 ——— ROME (part.), pp. 18, 19.
1946 ——— VAN DEN BOLD, p. 23.
1948 ——— KINGMA, p. 20.
1953 ——— GREKOFF, p. 283.
1956 ——— MERTENS, p. 184.
1958 ——— HOWE and LAURENCICH, p. 149.

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1) Complete earlier references are listed in JONES (1849, p. 8).
2) Generic name *Cytheree* was used.
3) First designation of type-species.
4) Entire description refers to *Leptocythere*.

Diagnosis: Cytherinae Ostracoda[1] with compressed thick carapace. Surface ornamented by punctations owing to the apertures of sieve-like normal pore canals, punctae filling interstices between these punctations, and indentations superimposed over the punctate surface. Crenulation of the median hinge element is distinct. No vestibule. Marginal area fairly broad. A few of the radial pore canals are slightly bent at their midlength.

Remarks: There were two tendencies in the concept of the genus *Cythere* in the first half of the twentieth century. One was originated by G.W. MÜLLER (1894, 1912) and his followers (ex. HIRSCHMANN, 1912; SHARPE, 1909; ROME, 1942) who conbined the genera *Cythere* and *Leptocythere.* The other was originated by G.O. SARS and his followers (ex. KLIE, 1938) who include *Cythere lutea, albomaculata* and *viridis* in the genus *Cythere. Cythere albomaculata* and *viridis* are now the type-species of the genera *Heterocythereis* ELOFSON, 1941, of the subfamily Hemicytherinae and *Hirschmannia* ELOFSON, 1941, of the subfamily Loxoconchinae, respectively.

More recently, the concept of the genus *Cythere* has been more and more restricted to comprise the species closely related to *Cythere lutea*, the type-species of the genus. However, confusion in the concept of the genus *Cythere* is still encountered in some papers.

Cythere lutea O.F. MÜLLER

Cythere lutea O. F. MÜLLER, 1785, Entomostraca seu Insecta Testacea, p. 65, pl. 7, figs. 3,4; ZENKER, 1854, Arch. Naturgesch. Jahrgang 20, Bd. 1, pp. 83, 84, pl. 5, c; (not) FISCHER, 1855, Abh. bayer. Akad. Wiss., Bd. 7, pp. 658, 659, pl. 20, figs. 13, 14, 17b; SARS, 1866, Forh. Vidensk. Selsk. Krist., 1865 (1866), pp. 28, 29; BRADY, 1868, Trans. Linn. Soc. London, Zool., vol. 26, (1868–1870), pp. 395, 396, pl. 28, figs. 47–56; pl. 39, fig. 2; BRADY, CROSSKEY and ROBERTSON, 1874, Mon. Pal. Soc. London, p. 148, pl. 3, figs. 1–6; (not) G. W. MÜLLER, 1880, Z. ges. Naturwiss., Bd. 53 (ser. 3, Bd. 5), pp. 237, 238, pl. 5, fig. 1; CARUS, 1885, Prodromus Faunae Mediterraneae, vol. 1, p. 294; DAHL, 1888, Zool. Jb., pp. 605–607, pl. 1, figs. 1–12, 27–29; BRADY and NORMAN, 1889, Sci. Trans. Dublin Soc., vol. 4, ser. 2, (1888–1892), p. 125; G. W. MÜLLER, 1912, Das Tierreich, Lief. 31, p. 318; SARS 1925, An Account of the Crustacea of Norway, vol. 9, (1922–1928), pp. 167, 168, pl. 77; BLAKE, 1931, Jour. Paleontology, vol. 5, pp. 160, 161, figs, 1, b–e; KLIE, 1938, Die Tierwelt Deutschlands, Teil 34, pp. 164, 165, figs. 544–547; SYLVESTER-BRADLEY, 1941, Ann. Mag. Nat. Hist., ser. 2, vol. 8, pp. 27–32.

Monoculus luteus GMELIN, 1788, LINNÉ'S Systema Naturae, 13th ed., tom 1, pars 5, p. 3001.

Cytherina lutea LAMARCK, 1818, Histoire naturelle des animaux sans vertebres, vol. 5, p. 125.

Cythere reniformis BAIRD, 1835, Hist. Berwicksh. Nat. Club, vol. 1, p. 98, pl. 3, fig. 5; BAIRD, 1837, Mag. Zool. Bot., vol. 2, (1837–1838), p. 142, pl. 5, figs. 16–22; BAIRD, 1850, Roy. Soc. London, p. 169, pl. 20, fig. 5.

Cythere Zenkeri FISCHER, 1855, Abh. bayer. Akad. Wiss., Bd. 7, p. 656.

Cythere setosa BRADY, 1866, Trans. Zool. Soc. London, vol. 5, (1862–1866), p. 372, pl. 58, figs. 12, 13, 15.

Cythere viridis (part.) BRADY, 1868, Trans. Linn. Soc. London, Zool., vol. 26, (1868–1870), p. 397, pl. 28, figs. 40, 41, 50–55d; pl. 38, fig. 8.

Diagnosis: *Cythere* with irregularly radiating ridges superposed over the punctate surface, making a circle of about ten broad indentations.

Description: The carapace of this species was carefully described by BLAKE (1931,

1) Three diagnostic features of the subfamily Cytherinae are described on p. 409.

pp. 160, 161) and by SYLVESTER-BRADLEY (1941, pp. 27–32). Internal organs were admirably described and illustrated by SARS (1925, pp. 167, 168).

Cythere lutea uranipponica HANAI, n. subsp.
Pl. XXVIII, figs, 2, 6a, b; text-figs. 2a, b.

Holotype: Geol. Inst., Tokyo Univ., CA 3333, a right valve, pl. XXVIII, fig. 2; text-fig. 2b.
Figured paratypes: Geol. Inst., Tokyo Univ., CA 3336, a left valve, pl. XXVIII, fig. 6b; text-fig. 2a: CA 3337, a right valve, pl. XXVIII, fig. 6a.
Name: Japanese Uranippon means Japan Sea side of Japan.
Type horizon and locality: Pliocene Sawane formation. The cliff at Mano Bay, Sawanemachi, Sadogun, Niigata Prefecture.
Diagnosis: *Cythere lutea* with rather deep indentations owing to the development of strong ridges surrounding the indentation in the posterior half of the carapace.

This subspecies has so far been found only on the Japan Sea side of Japan.
Description: Carapace thick, rather compressed, subreniform in lateral outline, highest at the middle. Anterior margin obliquely and broadly rounded, dorsal margin gently arched, ventral margin sinuate at midlength, posterior margin somewhat angulate in the middle. Viewed dorsally, carapace oblong ovate in outline, thickest posteriorly. Anterior end narrower than the posterior, both obtusely angled. Viewed anteriorly, ovate in outline. The right valve larger and overlapping the left, especially in the dorsal area. The margin of the right valve projects over that of the left along the hinge margin. The margin of the left valve projects over that of the right in the upper half of the anterior and posterior margins.

Surface ornamented by scattered large punctations due to the large apertures of the sieve-like normal pore canals. Interstices between these punctations are densely covered with smaller pits. Superimposed over these two kinds of punctations there are irregularly radiating indentations. The pattern of these indentations characterizes the subspecies. A blunt ridge runs along the ventral area of both valves. Marginal area moderately broad. Vestibule not developed. Radial pore canals simple, nearly straight, not numerous in number. Some of them are slightly bent in the middle. Hinge merodont. In the right valve, anterior and posterior elements are dentate and median element is crenulate with a series of pits. The left valve hingement is complementary. Adductor muscle scars consist of four horizontally elongated scars arranged in a little oblique row, with two additional scars in front of them. The upper scar of the two front scars is large and sometimes consists of two small closely placed scars, while the bottom scar is small and obscure.
Dimensions: Holotype (a right valve) length 0.75mm., height 0.44mm., thickness 0.20mm.; paratypes (a left valve) length 0.70mm., height 0.43mm., thickness 0.18 mm.; (a right valve) length 0.76mm., height 0.45mm., thickness 0.20mm.; (a left valve) length 0.76mm., height 0.43mm., thickness 0.20mm.
Remarks: *Cythere lutea* O.F. MÜLLER from the Japan Sea side of Japan (*i. e.* from Sawane (Pliocene) formation and from the mouth of the Onga River (Recent)) is different from those obtained from the Pacific side of Japan (*i. e.* from Hayamamachi (Recent), and from Shirahama, Izu (Recent) in the ornamentation, especially having indentations superimposed over the punctate surface of the carapace. In spite of the difference in and some difference in size, specimens from the Sawane

Pliocene have surface indentations identical with those of Recent specimens from the mouth of the Onga River.

Cythere lutea omotenipponica Hanai, n. subsp.

Pl. XXVIII, figs. 5a, b.

Holotype: Geol. Inst., Tokyo Univ., CA 3338, a right valve, pl. XXVIII, fig. 5a.
Figured paratype: Geol. Inst., Tokyo Univ., CA 3339, a left valve, pl. XXVIII, fig. 5b.
Name: Japanese Omotenippon means the Pacific side of Japan.
Type horizon and locality: Recent beach sand from the shore behind an Imperial villa, Hayamamachi, Kanagawa Prefecture.
Diagnosis: Interstitial area between punctations representing apertures of normal pore canals becomes very thick to form ridges around each puncta. This obscures the indentations superimposed over the punctate surface. However, indentations still remain in the anteroventral and posteroventral areas.
Description: Same as the description for subspecies *Cythere lutea uranipponica*, except for surface ornamentation which is described in the diagnosis characterizing this subspecies.
Dimensions: Holotype (a right valve) length 0.66mm., height 0.39mm., thickness 0.14mm.; paratypes (a left valve) length 0.83mm., height 0.40mm., thickness 0.20 mm.; (a right valve) length 0.63mm., height 0.37mm., thickness 0.18mm.; (a left valve) length 0.72mm., height 0.41mm., thickness 0.20mm.

Cythere japonica Hanai, n. sp.

Pl. XXVIII, figs. 1, 3, 7a, b; text-figs. 3a, b.

Holotype: Geol. Inst., Tokyo Univ., CA 3342, a right valve, pl. XXVIII, fig. 7a; text-fig. 3b.
Figured paratypes: Geol. Inst., Tokyo Univ., CA 3344, right valve, pl. XXVIII, fig. 1: CA 3345, a left valve, pl. XXVIII, figs. 3, 7b; text-fig. 3a.
Type horizon and locality: Pliocene Sawane formation. The cliff at Mano bay, Sawanemachi, Sadogun, Niigata Prefecture.
Diagnosis: *Cythere* with subtrapezoidal outline and rather smooth surface. Ridges and indentations are very poorly developed in anteroventral, ventral and posteroventral areas.
Description: Carapace subtrapezoidal in lateral outline. Anterior margin obliquely rounded in its lower half gradually straightening in the upper half. Dorsal margin slightly arched in the left valve and moderately arched in the right, which projects over the left along the hinge margin. Ventral margin nearly straight. Posterior margin nearly straight in its upper half and rather arched in its lower half, meeting at narrowly rounded posterior end to make subacuminate posterior margin. Viewed dorsally valves appear fusiform, thickest a little posterior to the middle. Anterior view svbovate.

Surface ornamented by numerous punctations which are the apertures of the sieve-like normal pore canals. Some of these punctations are arranged parallel to and close to the dorsal margin. Between these punctations are numerous small punctae. Superimposed over these two kinds of punctations are very faint ridges and indentations which develop only in the anterior and posterior areas. A faint ridge appears in the anteroventral area, runs posteriorly along the ventral margin and ends in the posteroventral area.

Hinge merodont as in *Cythere*. Nature of the marginal area and adductor muscle scars typical of the genus.

Dimensions: Holotype (a right valve) length 0.78mm., height 0.51mm., thickness 0.21mm.; paratypes (a left valve) length 0.77mm., height 0.49mm., thickness 0.20 mm.; (a right valve) length 0.80mm., height 0.51mm., thickness 0.23mm.; (a left valve) length 0.76mm., height 0.48mm., thickness 0.23mm.

Remarks: From *Cythere lutea* O.F. MÜLLER, this species differs in its general outline and the ornamentation superimposed on the punctate surface. This new species occurs associated with *Cythere lutea uranipponica* HANAI in its type locality. However, the difference between the two species mentioned above is quite distinct, and no intergradation can be observed.

Genus *Loxocythere* HORNIBROOK, 1952

Type-species: *Loxocythere crassa* HORNIBROOK, 1952

1952 *Loxocythere* HORNIBROOK, p. 30.
1952 *Tetracytherura* RUGGIERI, p. 86.

Diagnosis: Cytherinae Ostracoda with inflated carapace. Surface ornamented by punctations of the apertures of the sieve-like normal pore canals and reticulations superimposed over punctated surface. Ventral ridge fairly strong. Crenulation of the median hinge element is usually obscure. Vestibule usually present. Marginal area narrow with prominent selvage line. Radial pore canals are straight and have rather wide bases.

Remarks: The genus *Loxocythere* of original sense is characterized by a non-crenulate median hinge element, radial pore canals with wide bases, and a line of concrescence which does not coincide with the inner margin. The Japanese *Loxocythere*, however, is much closer in relationship to the genus *Cythere* than the New Zealand species in having minute crenulations on the median hinge element and a line of concrescence which almost coincides with the inner margin.

In many respects, the genus *Loxocythere* has characters intermediate between the genera *Cythere* and *Cytheropteron*.

Loxocythere inflata HANAI, n. sp.

Pl. XXVIII, figs. 4a, b; text-figs. 1a, b,

Holotype: Geol. Inst., Tokyo Univ., CA 3346, a right valve, pl. XXVIII, fig. 4a.

Figured paratypes: Geol. Inst., Tokyo Univ., CA 3347, a left valve, pl. XXVIII, fig. 4b; text-fig. 1a; CA 3348, a right valve, text-fig. 1b.

Name: Latin inflatus means inflated.

Type horizon and locality: Pliocene Sawane formation. The cliff at Mano bay, Sawanemachi, Sadogun, Niigata Prefecture.

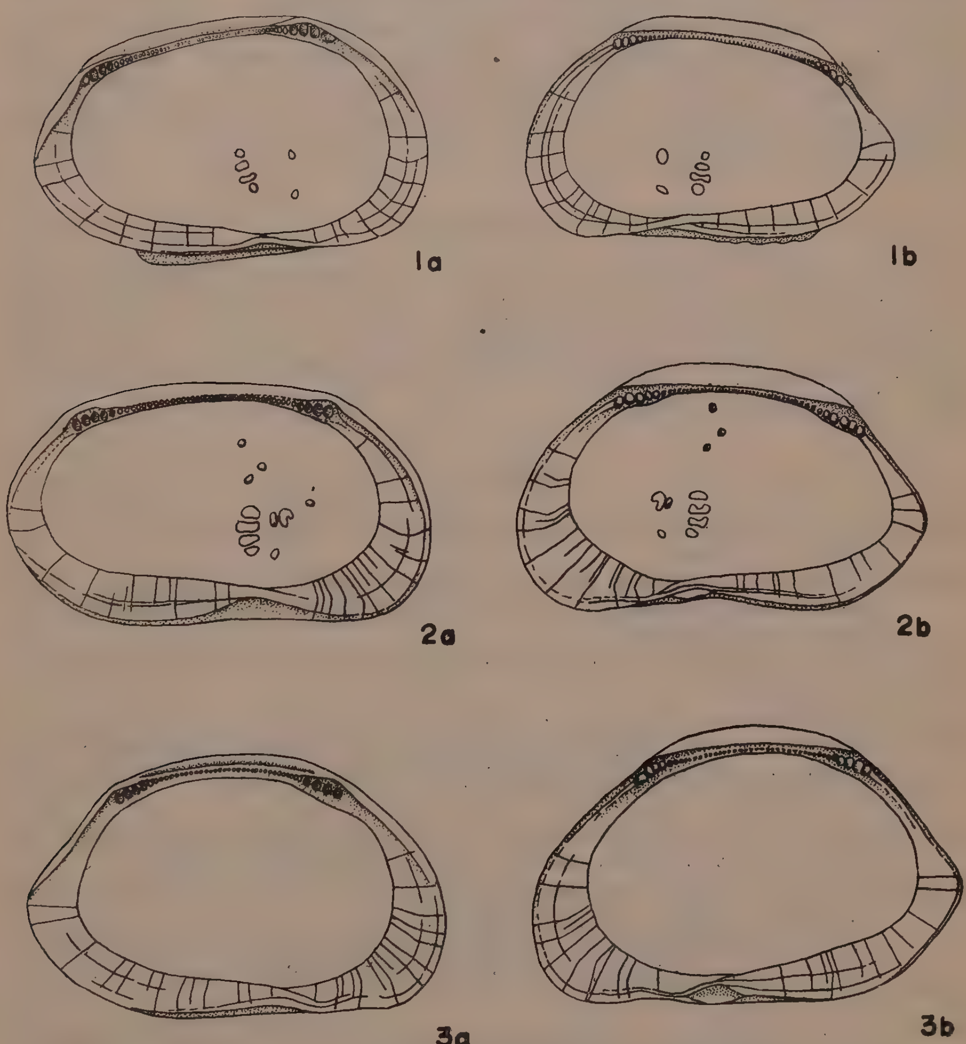
Diagnosis: *Loxocythere* with rather large carapace. Surface ornamented by weak reticulations. Vestibule weakly developed. Crenulation of median hinge element observable.

Description: Carapace of the left valve subovate in side view. Dorsal margin of the right valve heightened to project over the left in the region of the hinge. Anterior margin broadly and a little obliquely rounded, dorsal margin slightly arched, ventral margin nearly straight, posterior end narrowly rounded to make subacuminate posterior margin. This calls to mind the caudal process developed

in cytheropterid Ostracoda. Viewed dorsally valves moderately inflated, thickest in the middle. Anterior view bell-shaped owing to the flat ventral surface.

Surface ornamented by weak reticulations which are superimposed over the small punctations of the aperture of normal pore canals. Six or seven punctations are arranged close to and parallel to the dorsal margin. A blunt ridge appears in the anteroventral area, runs posteriorly along the edge of the ventral flattened area, and ends in the posteroventral area.

Hinge merodont, of *Cythere* type. Anterior and posterior teeth of the right valve consist of four to five rounded projecting teeth. Under high power magnification, median element of the right valve consists of a minutely socketed shelf.



Text-figures 1–3. Internal views of the cytherid carapaces.
a. left valve: b. right valve.
Figs. 1a, b. *Loxocythere inflata* HANAI, n. sp. (CA 3347, CA 3348)
Figs. 2a, b. *Cythere lutea uranipponica* HANAI, n. subsp. (CA 3336, CA 3333)
Figs. 3a, b. *Cythere japonica* HANAI, n. sp. (CA 3345, CA 3342)

Hingement of left valve is complementary to that of the right. In the right valve, flange well developed, overhanging the actual hinge element. Marginal duplicature narrow with a few simple, straight, radial pore canals. Pseudoradial pore canals also well developed. Vestibule extremely weak. Interior has scattered clear punctations of normal pore canals. Adductor muscle scars consist of a vertical row of at least four, one in front, and two above. A depression is present just in front of the four vertical muscle scars.
Dimensions: Holotype (a right valve) length 0.70mm., height 0.43mm., thickness 0.23mm.; paratypes (a left valve) length 0.72mm., height 0.43mm., thickness 0.21 mm.; (a right valve) length 0.69mm., height 0.41mm., thickness 0.21mm.; (a left valve) length 0.69mm., height 0.43mm., thickness 0.21mm.
Remarks: The ornamentation and general outline of this species are close to those of *Loxocythere kingi* HORNIBROOK, 1952, from New Zealand. However, the Japanese species is larger and shows a weaker development of the vestibule. The outline and ornamentation of this species are also different in detail from those of New Zealand species.

Conclusion

The subfamily Cytherinae s. str. is close to the subfamily Cytheropterinae HANAI in its shell structures. Hinge structures of the subfamilies are transitional without distinct gap. Thus both subfamilies can be placed in the same family. Merodont hingements of the Cytherinae and Cytheropterinae are different from those of the Cytherideidae.

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Nomenclatural notes

1) Dr. G. RUGGIERI of Bologna, Italy, and W. A. VAN DEN BOLD of Baton Rouge, La., U.S.A. have kindly informed me that the name *Cytheropteron rarum* HANAI 1957 (Jour. Fac. Univ. Tokyo, sec. 2, vol. 11, pt. 1, p. 28) is preoccupied by *Cytheropteron rarum* G. W. MÜLLER 1894 (Fauna und Flora des Golfes von Neapel, 21 Monographie, p. 304). As replacement, I hereby propose the new specific trivial name *eremitum* for *Cytheropteron rarum* HANAI 1957 (non *Cytheropteron rarum* G. W. MÜLLER 1894).

2) Professor H. V. HOWE of Baton Rouge, La., U. S. A. was kind enough to advise me that the generic name *Neocyprideis* HANAI 1959 (Jour. Fac. Sci. Univ. Tokyo, sec. 2, vol. 11, pt. 3, p. 299) is a homonym of *Neocyprideis* APOSTOLESCU 1956 (Inst. Franç. Pétrole, Rev., vol. 11, no. 11, p. 1337). I, therefore, propose the generic name *Parakrithella* as a substitute for *Neocyprideis* HANAI 1959 (non *Neocyprideis* APOSTOLESCU 1956).

T. HANAI

Studies on the Ostracoda from Japan
V. Subfamily Cytherinae DANA, *1852 (emend.)*

Plate XXVIII

Explanation of Plate XXVIII

All figures ×82

Figs. 1, 3, 7. *Cythere japonica* HANAI, n. sp.

1. Anterior marginal area of right valve (CA 3344) photographed under water by transmitted light to show radial pore canals. (×100)

3. Hingement of left valve (CA 3345). (×155)

7a, b. External lateral views of right and left valves (CA 3342, CA 3345).

Figs. 2, 6. *Cythere lutea uranipponica* HANAI, n. subsp.

2. Hingement of right valve (CA 3333). (×165)

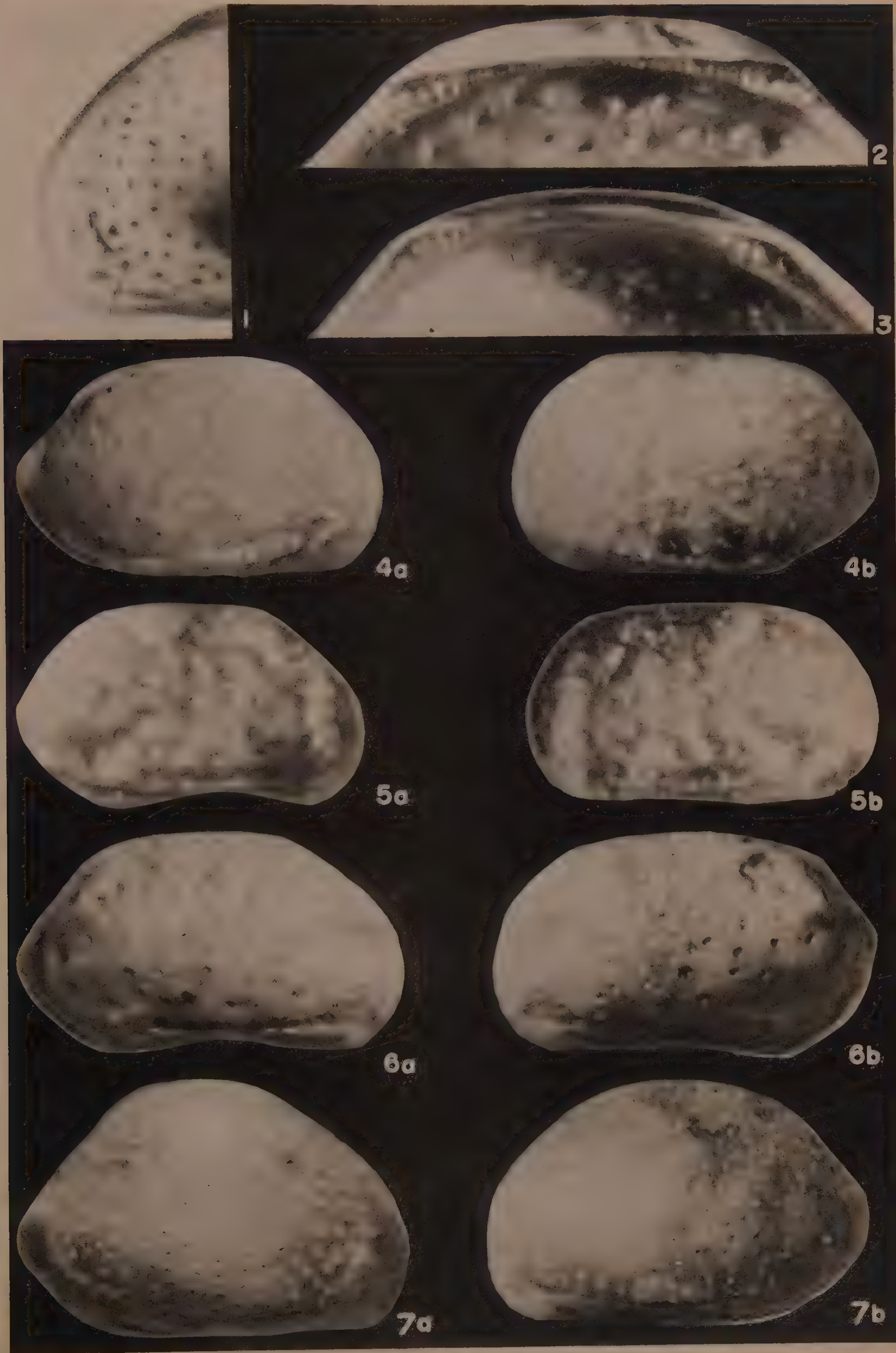
6a, b. External lateral views of right and left valves (CA 3337, CA 3336).

Fig. 4. *Loxocythere inflata* HANAI, n. sp.

4a, b. External lateral views of right and left valves (CA 3346, CA 3347).

Fig. 5. *Cythere lutea omotenipponica* HANAI, n. subsp.

5a, b. External lateral views of right and left valves (CA 3338, CA 3339).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STUDIES ON THE OSTRACODA FROM JAPAN

Historical Review

*with Bibliographic Index of Japanese Ostracoda**

By

Tetsuro HANAI

Abstract

The history of the study of Japanese Ostracoda is reviewed here in order to clarify its present status. A bibliographic index of Japanese Ostracoda is also presented.

Contents

Introduction and acknowledgment

Ostracoda have been studied extensively as well as intensively in many parts of the world during the past quarter of a century, primarily because of their importance in petroleum geology. However, little study in this field has been done in Asiatic countries. Thus, in 1951, upon the suggestion of Professor T. KOBAYASHI, the writer commenced his study on Asiatic Ostracoda (HANAI, 1951).

At present in East Asia, Drs. Y. T. HOU and T. C. CHEN of the Chinese Academy, Peking, is advancing the study of Paleozoic and Mesozoic Ostracoda in China. Mr. Y. NAGAPA of the Assam Oil Co., Assam, India, is studying Ostracoda from the oil-bearing Tertiary in Assam. Further, in the East Indies, Dr. A. J. KEIJ is advancing a study already established by KINGMA (1948) and others. The present number of ostracod paleontologists, however, is still too small in comparison with the extensive area we should cover.

In his comprehensive study of Cretaceous Ostracoda of the world, Professor H.V. HOWE pointed out the necessity of studying Asiatic Ostracoda (HOWE, 1956, abstract). As a matter of fact, during my stay in Louisiana State University, Baton Rouge, Louisiana, U.S.A., Professor HOWE suggested, first of all, that a card catalogue of the Asiatic Ostracoda should be made. This study was therefore initiated at Louisiana State University in order to clarify the present status of ostracod study in Japan, and was almost completed in 1953. The research was completed at the University of Tokyo under the direction of Professors T.

Received April 6, 1959.

* In this paper, the species described in my series of papers published in "Studies on the Ostracoda from Japan" are excluded.

KOBAYASHI and F. TAKAI, mainly involving the addition of some older Japanese papers. To Professors T. KOBAYASHI and F. TAKAI of the University of Tokyo and to Professor H. V. HOWE of Louisiana State University I should like to express my deep gratitude for their many valuable suggestions and constructive criticism. Mr. R.L. ARTUSY of New York University and Mr. R. W. MORRIS of the Arabian American Oil Co. kindly read the manuscript. To these people I am also deeply indebted.

Historical review

The first contribution to the knowledge of Japanese Ostracoda was made in 1866 by G. S. BRADY. In this paper "On new or imperfectly known species of marine Ostracoda", BRADY described two new species collected by A. ADAMS from Japan. On the basis of one of these species, *Heterodesmus adamsii* BRADY, he proposed a new genus *Heterodesmus* BRADY 1866. The other species was *Cypridina japonica* BRADY. Generic identification of these species was quite correct. However, the locality or localities where A. ADAMS obtained these materials are unknown and thus they lose much of their value.

The next contribution was made by G. S. BRADY in 1880 in his report on the Ostracoda collected by the Challenger Expedition. H.M.S. Challenger came up from the Admirality Islands to Yokohama, Japan in 1875. After a short cruise along the southern coast and into the Inland Sea of Japan (=Setonaikai), the Challenger left Yokohama for Honolulu. Among many Ostracoda species collected by this expedition from the sea surrounding the Japanese Islands was *Cythere scabrocuneata* BRADY from the Inland Sea of Japan, the type species of the genus *Trachyleberis* BRADY 1898. Type specimens of this species were recently redescribed in great detail by HARDING and SYLVESTER-BRADLEY. The species from Japan and its environs, as reported in the Challenger Report are as follows:

Station 231, Tow-net, May 11, 1875.

Halocypris atlantica LUBBOCK 1862.
H. brevirostris (DANA) 1852.
H. imbricata BRADY 1880.

Station 233b, Inland Sea, Japan, Lat. 34°20′ N., long. 133°35′ E., 15 fathoms, Mud, May 20, 1875.

Cythere acupunctata BRADY 1880.
C. bicarinata BRADY 1880.
C. cymba BRADY 1869.
C. quadriaculeata BRADY 1880.
C. hodgii BRADY 1866.
C. darwini BRADY 1880.
C. scabrocuneata BRADY 1880.
Krithe hyalina BRADY 1880.
Loxoconcha sinensis BRADY 1869.

Station 241, Lat. 35°41′ N., long. 157°42′ E., 2300 fathoms, Bottom temperature 1.1° C, Red clay, June 23, 1875.

Cythere suhmi BRADY 1880.

Station 241, Tow-net, June 23, 1875.

Ostracoda obtained were the same species as those from the station 231.

In 1890, G.W. MÜLLER described following seven species of Myodocopa Ostracoda from Japan:

Cypridina hilgendorfii G. W. MÜLLER 1890.
Pyrocypris japonica G. M. MÜLLER 1890.
Philomedes japonica G. W. MÜLLER 1890.
P. sordida G. W. MÜLLER 1890.
Asterope brevis G. W. MÜLLER 1890.
A. hilgendorfii G. W. MÜLLER 1890.
A. fusca G. W. MÜLLER 1890.

These species were collected by F. HILGENDORF from various localities in Japan including Enoshima in Kanagawa Prefecture and Hakodate in Hokkaido. In this paper, a new genus *Pyrocypris* G.W. MÜLLER was proposed on the basis of six species including *Pyrocypris japonica* G.W. MÜLLER from Enoshima. Later, however, the genus was considered to be synonymous with *Cypridina* (*Cypridina*) by SKOGSBERG in 1920. Among the species described, *Cypridina hilgendorfii* G.W. MÜLLER shows bioluminescence and occurs abundantly in the sea surrounding Japan. Therefore, its bioluminescence has been studied extensively by many biologists.

The first comprehensive taxonomic work on the Japanese Ostracoda was done by E. KAJIYAMA in 1912–1913 in his graduation thesis for the Zoological Institute, University of Tokyo. Materials he described were collected by himself at Misaki in Kanagawa Prefecture, Amakusa and Akase in Kumamoto Prefecture and Tomo in Hiroshima Prefecture. He described following 33 species, among them 19 species were new:

Cypridina hilgendorfii G.W. MÜLLER 1890
C. pellucida KAJIYAMA 1912
C. punctata DANA 1852
C. (*Pyrocypris*) *noctiluca* KAJIYAMA 1912
Philomedes japonica G.W. MÜLLER 1890
P. Ijimai KAJIYAMA 1912
Sarsiella misakiensis KAJIYAMA 1912
Cylindroleberis oblonga (GRUBE) 1859
C. fusca (G.W. MÜLLER) 1890
C. brevis (G.W. MÜLLER) 1890
C. quadrata (BRADY) 1898
Cylindroleberis obalis KAJIYAMA 1912
Pontocypris pirifera G.W. MÜLLER 1894
Bairdia oligodentata KAJIYAMA 1913
Cytheropteron videns G.W. MÜLLER 1894
Paradoxostoma coniforme KAJIYAMA 1913.
P. oblongum KAJIYAMA 1913.
P. ovulare KAJIYAMA 1913.
P. pilsum KAJIYAMA 1913.
P. quadratum KAJIYAMA 1913.
P. triangulum KAJIYAMA 1913.
P. Yatsui KAJIYAMA 1913.
Xestoleberis sagamiensis KAJIYAMA 1913.
Loxoconcha impressa (BAIRD) 1850.
L. bispinosa KAJIYAMA 1913.
Cythere rectangulata KAJIYAMA 1913.
C. Kishinouyei KAJIYAMA 1913.
Cythereis yamigera (BRADY) 1868.
C. darwini (BRADY) 1880.
C. hodgei (BRADY) 1866.

C. *convexa* (BAIRD) 1850.
C. *subconvexa* KAJIYAMA 1913.
C. *assimilis* KAJIYAMA 1913.

Ostracoda are found abundantly in dredgings as well as in beach samples from the sea surrounding Japan (IMANISHI 1954, NASU and SAITO 1958). However, many of these are still undescribed.

The first fresh-water ostracod *Cyprinotus kaufmanni* VAVRA was described by VAVRA in 1906 on the basis of the specimens collected by W. VOLZ at Nagasaki in 1902. In 1927, BREHM reported on 3 species of fresh-water Ostracoda (*Candona* sp. 1, *Candona* sp. 2, *Cytheridea* cf. *lacustris* G. O. SARS) collected by Y. AMAMIYA from Lake Aoki, Nagano Prefecture. In 1933, BREHM added three more species (*Notodromus monacha* O. F. MÜLLER, *Cypridopsis uenoi* BREHM, and *Cyprinotus* sp.), to the Japanese fresh-water Ostracoda. These species were based on specimens collected by M. UENO from Nagano and Niigata Prefectures. Recently, KATO (1944) reported *Stenocypris formosa* KLIE from Izu, Shizuoka Prefecture. This species was originally described from Formosa by KLIE (1938).

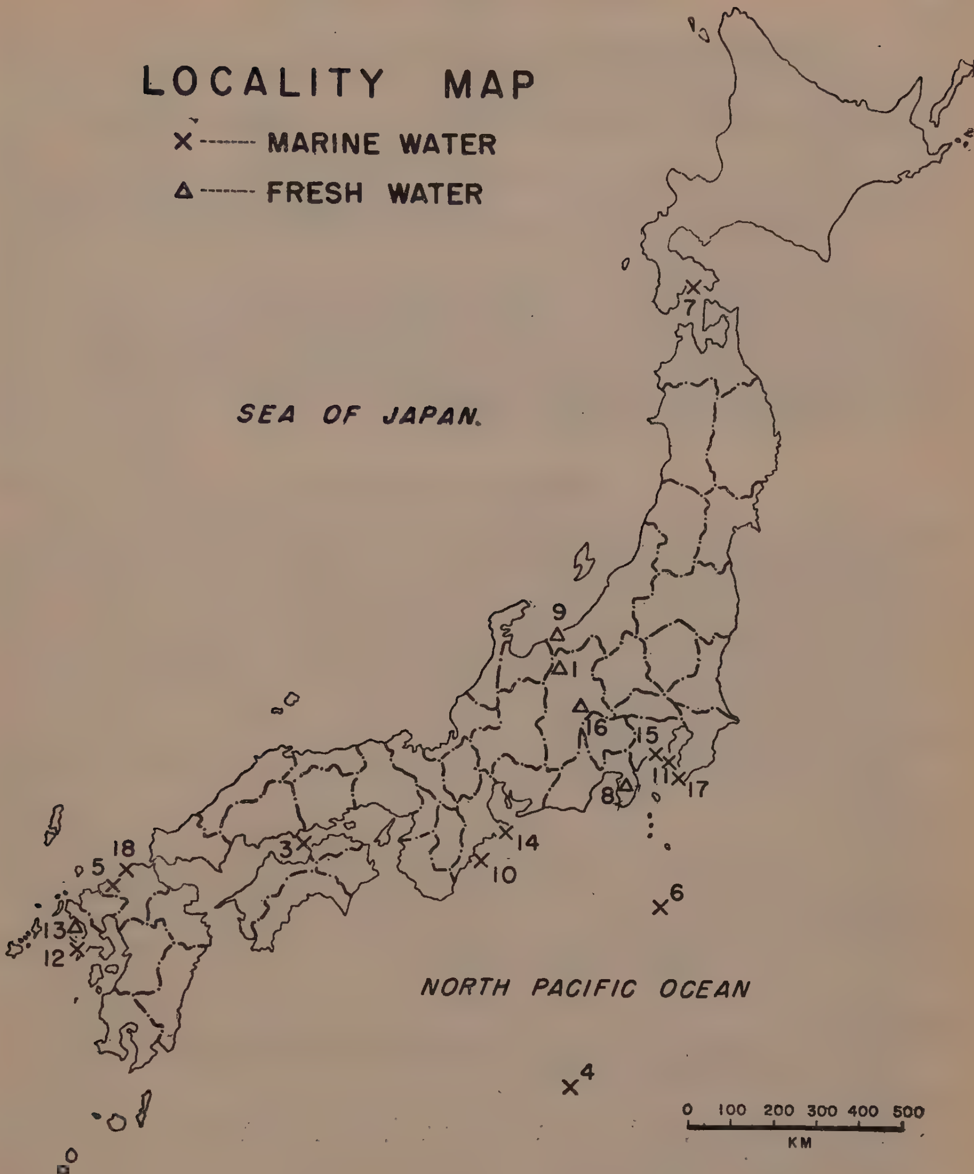
Cythere sp., reported by MAKIYAMA (1931) from the Kakegawa Pliocene in Sizuoka Prefecture, is the first record of fossil Ostracoda from Japan. In 1950, IMANISHI distinguished 10 species of *Bairdia* from Pliocene and Quaternary deposits. However, he did not name the species. Japanese Tertiary formations, especially Miocene and later, contain many species of Ostracoda. In fact, IMANISHI (1954) listed many Tertiary and young ostracod localities in Japan. However, they have not been studied previously owing to the difficulties involved in their identification.

Little is known so far of the Mesozoic and Paleozoic Ostracoda in Japan. Recently OHOTA (1956) found a locality in the Lower Cretaceous Wakino formation in Fukuoka Prefecture where cyprid Ostracoda occur rarely. KONISHI (1951, 1952) recorded the occurrence of Ostracoda from the Permian Imogadaira limestone in Fukui Prefecture. Recently, HAMADA (1959) discovered "*Leperditia*" *japonica* HAMADA from the Devonian Takaharagawa formation in Gifu Prefecture.

Another line of studies on the Japanese Ostracoda is the study of bioluminescence of *Cypridina hilgendorfii* G. W. MÜLLER. The luminous phenomena of *Cypridina* has long since attracted biologists' attention and many papers have been published on the collection method (KAJIYAMA 1912), distribution (KANDA 1922), ecology (NAKAMURA 1954), and life history of the luminous Myodocopa (OKADA and KATO 1946, 1949), anatomy of the luminous organ (YAZU 1917), as well as the physico-chemical nature of the bioluminescence (ARAKI 1950, HANEDA 1952, 1955, 1957, HAYASHI and OKUYAMA 1934, KANDA 1918, 1819, 1920 a, 1920 b, 1920c, 1920d, 1921a, 1921b, 1921c, 1922, 1924, 1928, 1929, 1930a, 1930b, NAKAMURA 1940, 1947, OKADA Y. K. 1926, TAGAKI 1936, WATANABE 1897a, 1897b). Result of the study on the bioluminescence of *Cypridina hilgendorfii* G. W. MÜLLER are well summarized in HARVEY's text book (HARVEY 1952).

Localities

1. Aokiko—Aokiko (Lake Aoki), Omachi-shi, Nagano Prefecture (BREHM 1927).
2. Challenger Station 241—1) Lat. 35°41′N., long. 157°42′E., 2,300 fathoms, Bottom temperature 1.1° C., Red clay. 2) Tow-net (BRADY 1880).
3. Challenger Station 233b—Inland Sea, Japan (Setonaikai), Lat. 34°20′N., long. 133°35′E., 15 fathoms, Mud (BRADY 1880).
4. Challenger Station 231—Lat. 31°8′N., long. 137°8′E., Tow-net (BRADY 1880).



5. Fukuoka Nishikoen—Nishikoen, Fukuoka-shi, Fukuoka Prefecture (KANDA 1922).
6. Hachijo Island—Hachijo Island, Tokyo-to (HANEDA 1957.)
7. Hakodate—Hakodate-shi, Hokkaido (G. W. MÜLLER 1890).
8. Izu—Izu Peninsula, Shizuoka Prefecture (KATO 1944).
9. Kajiyashiki—Kajiyashiki, Itoigawa-shi, Niigata Prefecture (BREHM 1933).
10. Kumano—Station 1, Lat. 33°51.2′N., long. 136°12.0′E., depth 191 meters: Station 2, Lat. 33°54.7′ N., long. 136°16.2′ E., depth 153 meters: Stations 3, Lat. 33°58.′8 N., long. 136°19.8′E., depth 152 meters: Station 4, Lat. 34°33.4′ N., long. 136°22.0′ E., depth 156 meters (NASU and SAITO 1958).
11. Miura—Miura (Aburatsubo); Aburatsubo cove, Koajiro, Miura-shi, Kanagawa Prefecture (KAJIYAMA 1912–1913, HORIKOSHI 1955). Miura (Koajiro); Koajiro cove, Koajiro, Miura-shi, Kanagawa Prefecture (KAJIYAMA 1912–1913). Miura (Misaki); Misaki-machi, Miura-shi, Kanagawa Prefecture (KAJIYAMA 1912–1913). Miura (Miyata); Miyata,

cove, Miura-shi, Kanagawa Prefecture (HORIKOSHI 1956).
12. Nagasaki—Osawa Temple (Bronze horse temple), Nagasaki, Nagasaki Prefecture (VAVRA 1906). (=Suwa-jinja, Uma-machi, Nagasaki)
13. Nagashima—Nagashima, Ogushi-mura, Nishisonoki-gun, Nagasaki Prefecture (KANDA 1922).
14. Sugashima—Sugashima, Shima-gun, Mie Prefecture (OKADA and KATO 1946).
15. Shonan—Shonan (Enoshima); Enoshima, Fujisawa-shi, Kanagawa Prefecture (G. W. MÜLLER 1890). Shonan (Inamuragasaki); Cape Inamuragasaki, Kamakura-shi, Kanagawa Prefecture (IMANISHI 1954).
16. Tamagawa—Tamagawa, Suwa-gun, Nagano Prefecture (BREHM 1933).
17. Tateyama—Tateyama-shi, Chiba Prefecture (OKADA and KATO 1946).
18. Tsuyazaki—Tsuyazaki-machi, Munekata-gun, Fukuoka Prefecture (KANDA 1922).
19. Uemura Oike—Uemura Oike, Simoina-gun, Nagano Prefecture (BREHM 1933). (=Kamimura Oike, Simoina-gun, Nagano Prefecture).

Catalogue of species[1]

Asteropteron fuscum (G. W. MÜLLER) 1890.

Asterope fusca, G. W. MÜLLER, 1890, Zool. Jb. System., v. 5, p. 242, 243, pl. 25, f. 11–13, pl. 27, f. 19–22, 25.

Cyclasterope fusca, G. W. MÜLLER, 1912, Das Tierreich, 31, p. 49, 50.

Cylindroleberis fusca, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 617, f. 31.

Asteropteron fuscum, SKOGSBERG, 1920, Zool. Bidrag Uppsala, Supple. Bd. 1, p. 443.

(Miura (Misaki), Miura (Aburatsubo), (KAJIYAMA 1912)).

Bairdia oligodentata KJIYAMA 1913.

Bairdia oligodentata, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 3. pl. 1, f. 10–18.

(Miura (Misaki), (KAJIYAMA 1913)).

Bairdia sp.

Bairdia sp., *NASU and SAITO, 1958, Rec. Oceanogr. Works Japan, spec. no. 2, p. 209.

(Kumano Station 2, (NASU and SAITO 1958)).

Bradleya (?) sp.

Bradleya (?) sp., *NASU and SAITO, 1958, Rec. Oceanogr. Works Japan, spec. no. 2, p. 209.

(Kumano Station 1, (NASU and SAITO 1958)).

Candona sp.

Candona sp., *BREHM, 1927, Arch. f. Hydrobiol., v. 18, p. 145, f. 23, 24.

(Aokiko, coll. by AMEMIYA, (BREHM 1927)).

Candona sp.

Candona sp., *BREHM, 1927, Arch. f. Hydrobiol., v. 18, p. 145, f. 25–27.

(Aokiko, coll. by AMEMIYA, (BREHM 1927)).

Conchoecia imbricata (BRADY) 1880.

Halocypris imbricata, BRADY, 1880, Challenger Rep., Zool., v. 1, p. 167, 168, pl. 41, f. 1, 3–9, pl. 42, f. 1–8.

Conchoecia imbricata, G. W. MÜLLER, 1891, Zool. Jb. System., v. 5, p. 277: BRADY, 1897, Trans. Zool. Soc. London, v. 14, p. 96: G. W. MÜLLER, 1906, Siboga Exp., Monogr. 30, p. 8: G. W. MÜLLER, 1906, Wiss. Ergebn. d. deutsch. Tiefsee-exp., v. 8, p. 118, 119, pl. 28. f. 1–6: OSTENFELD and WESENBERG-LUND, 1909, Conseil perm. intern. explor.

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1) Many of the old generic identifications in this catalogue are obsolete. However, little effort has so far been made to replace these old determinations with current terminology. It also seems probable that many species originally described from other parts of the world are incorrectly identified from Japanese material. All such identifications are included in this paper, however, pending clarification of their correct specific assignment. Species originally described from Japan are marked with an asterisk.

mer, Publ. circonstance, v. 48, p. 112: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 91: SKOGSBERG, 1920, Zool. Bidrag Uppsala, Supple. Bd. 1, p. 128.

Conchoecia armata, CLAUS, 1891, Arb. Zool. Inst. Univ. Wien u. Zool., Stat. Triest, v. 9 (1890), p. 19, 20: CLAUS, 1891, Die Haplocypriden des Atlantischen Oceans u. Mittelmeeres, Wien, p. 70, pl. 16, f. 1, 2–5, pl. 17, f. 1, 2–4, pl. 18.

Conchoecia plinthina G. W. MÜLLER 1906.

Halocypris imbricata, *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 167, 168, pl. 41, f. 2, 10.

Conchoecia plinthina, G. W. MÜLLER, 1906, Siboga Exp. Monogr. 30, p. 7: G. W. MÜLLER, 1906, Wiss. Ergebn. der deutsch. Tiefsee-exp., v. 8, p. 116, 117, pl. 27, f. 1–6, 9, 10: G.W. MÜLLER, 1912, Das Tierreich, 31, p. 90.

(The original description of *Halocypris imbricata* BRADY 1880 was actually based on two species, *Conchoecia imbricata* (BRADY) 1880 and *C. plintihina* G. W. MÜLLER 1906, from the various parts of the world including the sea surrounding Japan. Challenger Station 231, 241, (BRADY 1880)).

Conchoecia serrulata CLAUS 1874.

Conchoecia serrulata, CLAUS, 1874, Verh. Zool. Bot. Ges. Wien, v. 24, p. 176: CLAUS, 1874, Schrift. Zool. Inhalts Wien, Heft 1, p. 6, pl. 1, f. 2, 3–7, 9–11, pl. 2, f. 12, 13, 17, 19: G. W. MÜLLER, 1906, Wiss. Ergebn. der deutsch. Tiefsee-exp., v. 8, p. 97, 98, pl. 22, f. 24, pl. 23, f. 20–30: G. W. MÜLLER, 1908, Deutsch. Südpolar Exp. 1901–1903, v. 10, Zool., pt. 2, p. 73: *s. laevis*, G. W. MÜLLER, 1912, Das Tierreich, 31, p. 81, 82.

Halocypris atlantica, *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 164–166, pl. 40, f. 1–15, pl. 41, f. 11, 12.

Pseudoconchoecia serrulata, CLAUS, 1891, Arb. Zool. Inst. Univ. Wien u. Zool. Stat. Triest, v. 9 (1890), p. 20: CLAUS, 1891, Die Halocypriden des Atlantischen Oceans und Mittelmeeres, Wien, p. 72, pl. 19, [f. 1–14, pl. 23, f. 1–13: BRADY, 1897, Trans. Zool. Soc. London, v. 14, p. 96, 97, pl. 17, f. 22–24: var. *laevis*, BRADY, 1907, Nat. Antarctic Exp. 1901–1904, v. 3, Zool. and Bot., no. 5, Crustacea, Ostracoda, p. 2.

(Challenger Station 231, 241, (BRADY 1880)).

Cyclasterope hilgendorfii (G. W. MÜLLER) 1890.

Asterope hilgendorfii, *G. W. MÜLLER, 1890, Zool. Jb., System.,v. 5, p. 241, pl. 25, f. 15, pl. 26, f. 8, 12, pl. 27, f. 4–6, 17: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 44.

?Cyclasterope hendersoni, BRADY, 1897, Trans. Zool. Soc. London, v. 14, p. 86, 87, pl. 15, f. 1–12.

?Asterope arthuri, STEBBING, 1900, Willey Zool. Res., pt. 5, p. 660–662, pl. 72A.

Cylindroleberis hilgendorfii, G. W. MÜLLER, 1906, Siboga Exp., Monogr. 30, p. 33, 34, pl. 5, f. 1–5.

Cyclasterope hilgendorfii, SKOGSBERG, 1920, Zool. Bidrag Uppsala, Supple. Bd. 1, p. 441.

(Shonan (Enoshima), 12 fathoms, collected by HILGENDORF, (G. W. MÜLLER 1890)).

Cyclasterope brevis (G. W. MÜLLER) 1890.

Asterope brevis, *G. W. MÜLLER, 1890, Zool. Jb., System., v. 5, p. 239, 240, pl. 25, f. 10, 14, pl. 26, f. 7, 12, pl. 27, f. 7–10, 15, 16.

Cyclasterope brevis, BRADY, 1902, Trans. Zool. Soc. London, v. 16, p. 183, pl. 24, f. 16–22: G. W. MÜLLER, 1906, Siboga Exp., Monogr. 30, p. 35: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 49.

Cylindroleberis breris, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 617, 618, pl. 9, f. 32, 33.

Cycloleberis brevis, SKOGSBERG, 1920, Zool. Bidrag Uppsala, Supple. Bd. 1, p. 442.

(KLIE (1943, Zool. Anz., 143, p. 50) considered *Cycoleberis lobiancoi*, the genotype, to be *Cyclasterope*. Shonan (Enoshima), 12 fathoms, collected by HILEGENDORF, (G. W. MÜLLER 1890); Miura (Misaki), (KAJIYAMA 1912)).

Cylindroleberis mariae (BAIRD) 1850.

Cypridina mariae, BAIRD, 1850, Proc. Zool. Soc. London, v. 18, p. 257, pl. 17, f. 5–7.

Cypridina oblonga, GRUBE, 1859, Arch, f. Naturg., v. 25, pt. 1, p. 335, pl. 12, f. 2–5.

Philomedes mariae, BRADY, 1867, Rep. Brit. Assoc. Advance. Sci., 36th Meet., London 1866, p. 208.

Cylindroleberis mariae, NORMAN, 1867, Rep. Brit. Assoc. Advance. Sci., 36th Meet., London 1866, p. 198: BRADY, 1868, Intel. Obs., p. 128, pl. 2, f. 11–14: BRADY, 1868, Trans. Linn. Soc. London, v. 26, p. 465, pl. 33, f. 18–22, pl. 41, f. 1: NORMAN, 1869, Rep. Brit. Assoc. Advance. Sci., 38th Meet., London 1868, p. 259, 295: BRADY, 1875, Les Fonds de la Mer, v. 2, pt. 1, chap. 2, p. 11: CUSHMAN, 1906, Proc. Bost. Soc. Nat. Hist., v. 32, no. 10, p. 366, 367, pl. 29, f. 19–25: JUDAY, 1907, Univ. Calif. Publ., Zool., v. 3, p. 143, pl. 19, f. 7–11: SUMNER, OSBURN and COLE, 1913, Bull. U. S. Bur. Fish., v. 31 (1911), p. 636: FISH, 1926, ibid., v. 41 (1925), p. 141.

Asterope oblonga, (not) CLAUS, 1876, Untersuch. zur Erforsch. der genealogischen Grundlage des Crustaceen-Systems, Wien, p. 92, 93, pl. 17, f. 1–10: SARS, 1887, Arch. f. Mathem. Naturv., Kristian., v. 12, p. 203, pl. 1, f. 5–8, pl. 2, f. 1, 2, pl. 5, 6: GRAEFFE, 1900, Arb. Zool. Inst. Univ. Wien u. Zool. Stat. Triest, v. 13, p. 34.

Copechaete elongata, *Copechaete affinis*, HESSE, 1878, Ann. Sci. Nat., Zool., ser. 6, v. 7, art. 14, p. 2, pl. 12, f. 1, 7, p. 4, pl. 12, f. 3, 4, 6.

Cylindroleberis oblonga, G. W. MÜLLER, 1894, Fauna u. Flora des Golfes von Neapel, 21, p. 219, pl. 4, f. 14–18, 39, 41, 49–55, pl. 5, f. 1, 4, 5, 13, 14, 33, 41–44, pl. 8, f. 4: G. W. MÜLLER, 1908, Deutsch. Südpolar-Exped. 1901–1903, v. 10, Zool. pt. 2, p. 94: SHARPE, 1908, Proc. U. S. Nat. Mus., v. 35, p. 423, 424, pl. 62, f. 1–4: *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 616, 617, pl. 9, f. 29, 30: PARDILLO, 1912, Bol. Soc. Espan. Hist. Nat., v. 12, p. 370: O. DE BUEN, 1916, ibid., v, 16, p. 365.

Asterope mariae, BRADY, 1871, Proc. Zool. Soc. London, Sci. Meet., 1871, p. 295: (not) SARS, 1872, Vid. Selsk. Forh., Christiania (1871), p. 279: BRADY and ROBERTSON, 1872, Ann. Mag. Nat. Hist., ser. 4, v. 9, p. 59, 70: BRADY and ROBERTSON, 1874, ibid., ser. 4, v. 13, p. 115: BRADY and ROBERTSON, 1876, Rep. Brit. Assoc. Advance. Sci., 45th Meet., London 1875, p. 187: BRADY and NORMAN, 1896, Sci. Trans. Roy. Dublin Soc., v. 5, ser. 2, p. 630, pl. 50, f. 1–6, pl. 51, f. 11–22, pl. 52, f. 10–15: SCOTT, 1902, Fisheries, Scotland Sci. Invest., Glasgow, pt. 3, no. 9, p. 497, 509, 511, 517: BRADY, 1903, Trans. Nat. Hist. Soc. Northumberland etc., v. 14, p. 99: Marine Biol. Assoc., 1904, Jour. Marine Biol. Assoc., Plymouth, n. s., v. 7, no. 2: (not) OSTENFELD, 1906, Conseil perm. intern. explor. mer Publ. circonstance, 33, Copenhague, p. 96: (not) SCOTT, 1906, Proc. Roy. Phys. Soc. Edinburgh, v. 16, no. 7, p. 295: BRADY, 1909, Trans. Nat. Hist. Soc. Northumberland etc., n. s., v. 3, pt. 2, p. 359: (not) OSTENFELD and WESENBERG-LUND, 1909, Conseil perm. intsrn. explor. mer Publ. circonstance, 48, Copenhague, p. 112: G. W. MÜLLER, 1912, Das Tierreich, 31, p.45, 46: (part) SARS, 1922, An account of the Crustace of Norway, v. 9, pts. 1, 2, p. 17, 18, pl. 9, pl. 10, f. 1: (part) KLIE, 1929, Die Tierwelt der Nord- u. Ostsee, Lief. 16, p. 4: HARTMANN, 1954, Vie et Milieu, v. 4, fasc. 4, p. 649.

Asterope grimaldi, *Asterope grimaldi var. vicina*, SKOGSBERG, 1920, Zool. Bidrag Uppsala, Supple. Bd. 1, p. 510–522, f. 98–101.

(Miura (Misaki), Miura (Koajiro), (KAJIYAMA 1912)).

Cylindroleberis obalis KAJIYAMA 1912.

Cylindroleberis obalis, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 618, pl. 9, f. 29, 40.

(Miura (Misaki), (KAJIYAMA 1912)).

Cylindroleberis quadrata (BRADY) 1898.

Asterope quadrata, BRADY, 1898, Trans. Zool. Soc. London, v. 14, p. 432, pl. 45, f. 17–21: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 45.

Cylindroleberis quadrata, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 618, pl. 9, f. 34–38.

(Miura (Misaki), (KAJIYAMA 1912)).

Cypridina japonica BRADY 1866.

Cypridina japonica, *BRADY, 1866, Trans. Zool. Soc. London, v. 5, p. 386, pl. 62, f. 8 a-d: BRADY, 1880, Challenger Rep., Zool., v. 1, p. 153: BRADY, 1897, Trans. Zool. Soc.

London, v. 14, p. 88: (Cypridinidarum gen. dubia et sp. dubiae) G. W. MÜLLER, 1912, Das Tierreich, 31, p. 51.

(Japan, exact locality unknown, collected by A. ADAMS, (BRADY 1866)).

Cypridina pellucida KAJIYAMA 1912.

Cypridina pellucida, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 611, pl. 9, f. 9–11.

(Miura (Misaki), (KAJIYAMA 1912)).

Cypridina sp.

Cypridina punctata, (not) REUSS, 1849, Naturwiss. Abh. v. W. Haidinger, v. 3, p. 68, pl. 9, f. 24a, 24b: DANA, 1849, Proc. Am. Acad. Arts and Sci., v. 2, p. 51: DANA, 1853, U. S. Explor. Exp., v. 13, p. 1293, 1294, pl. 91, f. 2a, b: BRADY, 1880, Challenger Rep., Zool., v. 1, p. 153: BRADY, 1897, Trans. Zool. Soc. London, v. 14, p. 89, pl. 16, f. 5–9: *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 611, pl. 9, f. 12–14.

Cypridina sp., G. W. MÜLLER, 1912, Das Tierreich, 31, Ostracoda, p. 52.

(Miura (Misaki), (KAJIYAMA, 1912)).

Cypridina (Cypridina) noctiluca KAJIYAMA 1912.

Cypridina (Pyrocypris) noctiluca, *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 612, pl. 9, f. 15.

Cypridina noctiluca, *HANEDA, 1955, JOHNSON's Luminescence of Biol. Syst., Am. Assoc. Advance. Sci., Washington, p. 357, 358: *HANEDA, 1957, Rec. Oceanogr. Works Japan. spec. no., p. 98, 99.

(Miura (Misaki), (KAJIYAMA 1912); Hachijo Island, (HANEDA 1955, 1957)).

Cypridina (Cypridina) sp.

Pyrocypris japonica, *G. W. MÜLLER, 1890, Zool. Jb., System., v. 5, p. 233, 234, pl. 25, f. 2, pl. 26, f. 10: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 13.

(Since *Pyrocypris* is a synonym of *Cypridina* s. str. (SKOGJBERG 1920), *Pyrocypris japonica* G. W. MÜLLER 1890 is a secondary homonym of *Cypridina japonica* BRADY 1866, and, therefore, needs a new name. Shonan (Enoshima), collected by HILGEDORF, (G. W. MÜLLER 1890)).

Cypridina (Vargula) hilgendorfii G. W. MÜLLER 1890.

Cypridina hilgendorfii, *G. W. MÜLLER, 1890, Zool. Jb., System., v. 5, p. 228–230, pl. 25, f. 9, pl. 26, f. 1–3, pl. 27, f. 23, 30: G. W. MÜLLER, 1906, Siboga Exp. Monogr. 30, p. 13: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 12: *KAJIYAMA, 1912, Dobutsugaku-zasshi, v. 24, p. 610, 611, pl. 9, f. 1–8: *KANDA, 1922, ibid., v. 34, p. 545, 546: G. W. MÜLLER, 1927, Ostracoda *in* KUKENTHAL's Handbuch der Zool., p. 420, f. 373: *KOMAI, 1927, Illust. Encyc. of Fauna of Japan, p. 1192, f. 2298: *OKADA and KATO, 1946, Kagaku, v. 16, p. 64–66: *UENO, 1947, Illust. Encyc. of Fauna of Japan, rev. ed. p, 870, f. 2492: *OKADA and KATO, 1949, Bull. Biogeogr. Soc. Japan, v. 14, no. 3, p. 21–25: *HANEDA, 1955, JOHNSON's Luminescence of Biol. Syst., Am. Assoc. Advance. Sci., p. 356–358: *HORIKOSHI, 1955, Bull. Biogeogr. Soc. Japan, v. 16–19, p. 414: *HORIKOSHI, 1956, Misc. Rep. Res. Inst. Nat. Resources, nos. 41, 42, p. 64: *HANEDA, 1957, Rec. Oceanogr. Works Japan, spec. no., p. 98, 99.

Cypridina mediterranea, *WATANABE, 1897, Dobutsukagu-zasshi, v. 9, p. 86, 87.

Cypridina (Vargula) hilgendorfii, SKOGSBERG, 1920, Zool. Bidrag Uppsala., Supple. Bd. 1, p. 247.

(Coast of Japan, collected by HILGENDORF, (G. W. MÜLLER 1890): Miura (Misaki), (KAJIYAMA 1912): Tsuyasaki; Fukuoka Nishi-koen; Nagashima, (KANDA 1922): Tateyama; Sugashima, (OKADA and KATO 1946, 1949): Pacific coast of Japan, (UENO 1947): Miura (Moroiso, Aburatsubo, Miyata), (HORIKOSHI 1955, 1956)).

Cypridopsis uenoi BREHM 1933.

Cypridopsis uenoi, *BREHM, 1933, Trans. Nat. Hist. Soc. Formosa, nos. 128, 129, p. 297, 298: *UENO, 1947, Illust, Encyc. of Fauna of Japan, rev. ed., p. 871, f. 2497.

(Tamagawa, (BREHM 1933): Various localities in Honshu, (UENO 1947)).

Cyprinotus kaufmanni VAVRA 1906.

Cyprinotus kaufmanni, *VAVRA, 1906, Zool. Jb., System., v. 23, p. 424, 425, pl. 24, f. 15–20: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 166.

(Nagasaki, collected by VOLZ, (VAVRA 1906)).

Cyprinotus sp.

Cyprinotus sp., *BREHM, 1933, Trans. Nat, Hist, Soc. Formosa, nos. 128, 129, p. 298.

(Tamagawa, (BREHM 1933)).

Cythere acupunctata BRADY 1880.

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(Challenger Station 233b, 15 fathoms, (BRADY 1880)).

Cythere bicarinata BRADY 1880.

Cythere bicarinata, *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 70, pl. 16, f. 6 a-d: (not) CAPEDER, 1902, Atti R. Acc. Sci. Tornio, v. 37, p. 6, f. 2: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 371.

(Challenger Station 233b, 15 fathoms, (BRADY 1880)).

Cythere kishinouyei KAJIYAMA 1913.

Cythere kishinouyei, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 11, pl. 1, f. 61–63.

(Miura (Misaki), (KAJIYAMA 1913)).

Cythere rectangulata KAJIYAMA 1913.

Cythere rectangulata, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 10, 11. pl. 1, f. 56–60.

(Miura (Misaki), (KAJIYAMA 1913)).

Cythere suhmi BRADY 1880.

Cythere suhmi, *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 106, 107, pl. 26, f. 3 a–h: BRADY, 1881–1886, Les Fonds de la Mer, v. 4, pts. 10, 11. chap. 4, p. 165: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 365.

(Challenger Station 241, (BRADY 1880)).

Cythereis assimilis KAJIYAMA 1913.

Cythereis assimilis, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 14, pl. 1, f. 76.

(Miura (Misaki), (KAJIYAMA 1913)).

Cythereis cymba (BRADY) 1869.

Cythere cymba, BRADY, 1869, Les Fonds de la Mer, v. 1, chap. 31, p. 157, pl. 16, f. 1–4: *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 80, 81, pl. 20, f. 5 a–f.

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Cythereis hamigera, G. W. MÜLLER, 1912, Das Tierreich, 31, p. 363.

Cythereis yamigera, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 12, pl. 1, f. 64–66.

(Miura (Misaki), (KAJIYAMA 1913)).

Cythereis hodgei (BRADY) 1866.

Cythere hodgei, BRADY, 1866, Trans. Zool. Soc. London, v. 5, p. 373, pl. 59, f. 3 a, b: BRADY, 1868, Ann. Mag. Nat. Hist., ser. 4, v. 2, p. 179: BRADY, 1868, Les Fonds de la Mer, v. 1, p. 63, 64: BRADY, 1869, ibid., v. 1, p. 155: *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 94, 95, pl. 25, f. 1 a–d: BRADY, 1886, Jour. Linn. Soc. London, v. 19, p. 310: (not) EGGER, 1901, Abh. Boyer. Akad., v. 21, p. 431, pl. 6, f. 38–40: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 344.

Cythereis hodgei, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 13, pl. 1, f. 70, 71.

(Challenger Station 233b, 15 fathoms, (BRADY 1880): Miura (Misaki), (KAJIYAMA 1913)).

Cythereis quadriaculeata (BRADY) 1880.

Cythere quadriaculeata, *BRADY, 1880, Challenger Rep., Zool., v. 1, p. 86, 87, pl. 22, f.

2 a–d, pl. 25, f. 4 a–d: CHAPMAN, 1910, Jour. Linn. Soc. London, v. 30, p. 432: CHAPMAN, 1915, Zool. Res. of the Fishing Exped. carried on by F. I. S. Endeavour, 1909–1914, v. 3, p. 43: CHAPMAN, 1916, Brit. Antarc. Exped. 1907–1909, Geol., v. 2, pt. 3, p, 73, pl. 6, f. 47: CHAPMAN, 1926, Proc. Rev. Soc. Victoria, v. 38, n. s., p. 127, 128: CHAPMAN and CRESPIN, 1928, Rec. Geol. Surv. Victoria, v. 5, no. 1, p. 170.

Cythereis quadriaculeata, G. W. MÜLLER, 1912, Das Tierreich, 31, p. 357.

(Challenger Station 233b, 15 fathoms, (BRADY 1880)).

Cythereis sp.

Cythere darwinii, (not) BRADY, 1868, Les Fonds de la Mer, v. 1, p. 71. pl. 8, f. 17, 18: *BRADY, 1880, Challenger Rep., Zool.. v. 1, p. 97, 98, pl. 25, f. 2 a–g: (not) EGGER, 1901, Abh. Bayer. Akad., v. 21, p. 434, pl. 5, f. 3, 4.

Cythere sp., G. W. MÜLLER, 1912, Das Tierreich, 31, p. 323.

Cythereis darwinii, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 12, 13, pl. 1, f. 67–69.

(*Cythere darwinii* BRADY 1880 is not the same species as *Cythere darwinii* BRADY 1868, therefore, the species needs new name. Challenger Station 233b, 15 fathoms, (BRADY 1880): Miura (Misaki), (KAJIYAMA 1913)).

Cythereis subconvexa KAJIYAMA 1913.

Cythereis subconvexa, *KAJIYAMA, 1913. Dobutsugaku-zasshi, v. 25, no. 291, p. 14, pl. 1, f. 74, 75.

(Miura (Misaki), (KAJIYAMY 1913)).

Cytherella sp.

Cytherella sp., *NASU and SAITO, 1958, Rec. Oceanogr. Works Japan, spec. no. 2, p. 209.

(Kumano Station 2, (NASU and SAITO 1958)).

Cytherella sp.

Cytherella sp., *NASU and SAITO, 1958, Rec. Oceanogr. Works Japan, spec. no. 2, p. 209.

(Kumano Station 4, (NASU and SAITO 1958)).

Cytherissa lacustris (SARS) 1862.

Cyprideis torosa, (part) JONES, 1856, Palaeontogr. Soc. London, Monogr., p. 21, pl. 2, f. 1 a–i, woodcut p. 16, f. 2.

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Cytheridea lacustis, BRADY, 1868, Trans. Linn. Soc. London, v. 26, p. 427, pl. 26, f. 18–21, pl. 40, f. 21: BRADY and ROBERTSON, 1870, Ann. Mag. Nat. Hist., ser. 4, v. 9, p. 28, 32: BRADY and ROBERTSON, 1872, ibid., ser. 4, v. 9, p. 69: BRADY, CROSSKEY and *ROBERTSON, 1874, Palaeontogr. Soc. London, Monogr., p. 179, 180, pl. 6, f. 16–20: BRADY and NORMAN, 1889, Sci. Trans. Roy. Dublin Soc., ser. 2, v. 4, p. 176: KAUFMANN, 1896, Revue Suisse Zool., v. 4, p. 327, pl. 12, f. 1–19: SARS, 1903, Ann. du Mus. Zool. Acad. Sci., Petersburg, v. 8, p. 227: *var.*, HOFSTEN, 1912, Arch, Hydrobiol., vol. 7, p. 35, 36, f. 1: EKMAN, 1914, Zool. Bidrag Uppsala, v. 3, p. 26, f. 58–62: ALM, 1915. ibid., v, 4, p. 146, f. 90: *cf.*, *BREHM, 1927, Arch. f. Hydrobiol., v. 18, p. 145–147.

Acanthopus resistans, VERNET, 1879, Bull. Soc. Vaudoise, Lausanne, v. 5, p.509–516, pl. 27, f. 1–13, p. 527.

Cytheridea torosa, (part) G. W. MÜLLER, 1912, Das Tierreich, 31, p. 326.

Cytherissa lacustris, SARS, 1925, An Account of Crustacea of Norway, v. 9, pts. 9, 10, p. 153, 154, pl. 70: KLIE, 1938, Tierwelt Deutschland, Teil 34, Lief. 3, p. 154: TRIEBEL, 1941, Zeits, f. Geschiebeforsch., v. 17, no. 2, p. 72: BRONSTEIN, 1947, Fauna de l'URSS, Crustaces, v. 2, no. 1, Ostracoda, p. 279, 280, text-f. 180, 1–2: *var. baikalensis*, BRONSTEIN, 1947, ibid., p. 280–283, text-f. 181, 1–8, 182, 1–12, pl. 14, f. 3, 4: *var. dubitabilis*, BRONSTEIN, 1947, ibid., p. 283, text-f. 183, 1–2.

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(Aokiko, collected by AMEMIYA, (BREHM 1927)).

Halocypris inflata (DANA) 1849.

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Halocypris toynbeeana, LUBBOCK, 1862, Trans. Linn. Soc. London, v. 23, p. 189, pl. 29.

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Halocypris distincta, CLAUS, 1891, Arb. Zool. Inst. Univ. Wien u. Zool. Stat. Triest, v. 9 (1890), p. 25.

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Halocypris globosa, SCOTT, 1912, Trans. Roy. Soc. Edinburgh, v. 48, pt. 3, p. 587, pl. 13, f. 29–31.

(Challenger Station 231, 241, (BRADY 1880)).

Hemicytherura kajiyamai HANAI 1957.

Cytheropteron videns, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 4, 5, pl. 1, f. 19–25.

Hemicytherura kajiyamai, *HANAI, 1957, Jour. Fac. Sic., Univ. Tokyo, sec. 2, v. 11, pt. 1, p. 24, pl. 2, f. 1 a–d.

(Miura (Misaki), (*KAJIYAMA 1913)).

Herpetocypris intermedia KAUFMANN 1900.

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Cypris intermedia, var. *latialis*, MASI, 1905, Boll. Soc. Zool. Ital., ser. 2, v. 6, p. 124.

Heterodesmus adamsii BRADY 1866.

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?*Cypridina* (*Siphonostra*) *adamsii*, SKOGSBERG, 1920, Zool. Bidrag, Uppsala, Supple.

Bd. 1, p. 299, 300.

(Japan, exact locality unknown, collected by A. ADAMS, (BRADY 1866)).

Krithe hyalina BRADY 1880.

Krithe hyalina, *BRADY, 1880, Challenger Rep., Zool. v. 1, p. 115, pl. 27, f. 3 a–d: CHAPMAN, 1910, Jour. Linn. Soc. London, v. 30, p. 434: G. W. MÜLLER, 1912, Das Tierreich, 31, p. 336.

(Challenger Station 233b, 15 fathoms, (BRADY 1880)).

Loxoconcha bispinosa KAJIYAMA 1913.

Loxoconcha bispinosa, *KAJIYAMA, 1913, Dobutsugaku-zasshi, v. 25, p. 9, 10, pl. 1, f. 52–55.

(Miura (Misaki), (KAJIYAMA 1913)).

Loxoconcha rhomboidea (FISCHER) 1855

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?*Cythere flavida*, ZENKER, 1854, Archiv f. Naturg., v. 22, p. 86, pl. 5, f. B 1–4.

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(Miura (Misaki), (KAJIYAMA 1913)).

Loxoconcha sinensis BRADY 1869.

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(Challenger Station 233b, 15 fathoms, (BRADY 1880)).

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NOTES ON SOME JAPNAESE PERMIAN AND CRETACEOUS ALGAE AND THEIR STRATIGAPHIC SETTING*

(Studies on the Paleozoic marine Algae of Japan, 4)

By

Kenji KONISHI

With XXIX—XXXI. Plates

Abstract

Spongiostromata (oncoliths) are reported for the first time in Japan from the Permian, marine, Nabeyama formation of Central Honshu. Some allied objects classed as Problematica are mentioned from the Cretaceous of Western Honshu and Korea (South). *Anthracoporella spectabilis* PIA occurring in association with the Permian Spongiostromata is described to show its rôle as a cosmopolitan index fossil of the Early Permian.

Contents

Introduction and Acknowledgments

Though the Spongiostromata (the Cryptozoons and their allies) are not uncommon throughout the geologic column everywhere, there has been no record of their occurrence from Japan (e.g. YABE, 1952, p. 446), except one doubtfully named by KOBAYASHI (1936, p. 336–37) as "Cryptozoon-like fossil." During the repeated trips to the Kuzu area (Text–fig. 1), Tochigi Prefecture, Central Honshu, during 1950–54, the author obtained "calcareous objects" (POLINARD in Rept. Intern'l Geol. Congr. Br., 1951, p. 14) apparently resembling Recent algal biscuits. The main subject of this paper is to describe these objects referred to the Spongiostromata and the depositional environment where they were formed.**

* Received April 7, 1959.

** The first purpose of this paper was to get any clue to distinguish, by means of isotope chemistry, whether such calcareous objects are of organic origin or not. But, the author has to postpone this plan for some reasons. The excuse for this paper is merely the first report on the Spongiostromata from Japan.

Besides the Permian fossil, a similar, though problematical, material collected by KOBAYASHI and the author from the Cretaceous Kwanmon group (formerly the Inkstone series or group) is discussed.* Two other closely allied Cretaceous forms from South Korea are also noted.*

Fig. 1. Index Map Showing "Algal" Localities

In order to date the Kuzu Spongiostromata, the associated Dasycladacean, *Anthracoporella spectabilis*, is described with special reference to its stratigraphic distribution.

The author extends his thanks to Professor T. KOBAYASHI for his encouragement on this study; and to Professor Emeritus J.H. JOHNSON at the Colorado School of Mines, who kindly placed his library at the author's disposal, read the typescript, and contributed useful criticism. Thanks are also due to Dr. H. BESAIRIE of the Service Géologique de Madagascar for his cordial communication about the Madagascar algae; to Dr. H. YABE of the Japan Academy for his kind communication about the Korean Problematica; to Dr. I. TATEIWA, for valuable information on the Korean Cretaceous stratigraphy; to Professor T. MATSUMOTO of Kyushu University for data on the Kwanmon group; and to Professor H. KUNO of the University of Tokyo and Professor T. SUDO of Tokyo University of Education for advice from petrographic information. The author is also indebted to Mr. Y. UEDA of Kyushu University and to the Joban Mining Co., especially to Mr. N. TOYAMA, geologist of the company, for their kind assistance during the field work. The study was made possible by a Grant in Aid from the Scientific Research from the Ministry of Education, a grant from the Fulbright Fund, a research fellowship of the Colorado School of Mines, and a fellowship from the Japan Society. The author is grateful to these people and organizations.

Occurrence of the Permian Kuzu Spongiostromata

The Permian rock sequence around the Kuzu area (Text-fig. 1) has been

* See footnote in the preceding page.

summarized by YOSHIDA (1950–54) as follows.

Mikagura fmt.,	mainly composed of chert, 500 m. thick
Maki fmt.,	mainly composed of sandstone 1,100 m. thick
Adoyama fmt.,	mainly composed of chert 1,200 m. thick
Nabeyama fmt.	*Haku*–upper gray or pale gray massive limestone member, 115 m thick
	Doro–middle gray cryptocrystalline dolostone member, 105 m. thick
	Nezu–lower deep gray stratified limestone member, 100 m. thick
Aisawa fmt.,	mainly composed of sandstone associating with "schalstein," 700 m. thick

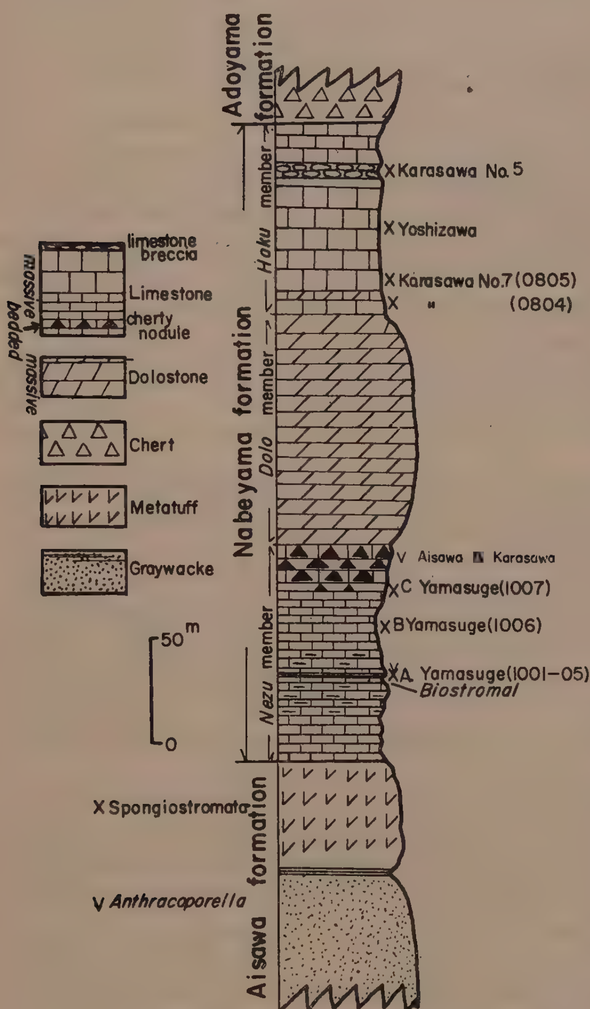

Fig. 2. Occurrence of Kuzu Algae

Most of the Kuzu specimens on which the following descriptions are based were collected from the outcrops of the *Nezu* member of the Nabeyama formation on the southern slope of Kurakake-yama hill, Yamasuge, Kuzu Town; the outcrops locate just behind a quarry of the Tokyo Lime Co. The beds whence the specimens were obtained are shown in Text-fig. 2. The algae are sufficiently abundant as to form an algal limestone about one meter thick; this can be traced for a distance of about 14 m. between faults.

Similar material occurs in the *Haku* member; however, the algae are much smaller in size than those in the *Nezu* and occur more sporadically.*

Another type of occurrence of the similar remains is found on the slope between the 3rd and 5th quarry (just opposite side of the 7th quarry), at Karasawa. They occur here as components of limestone breccia and suggest the allochtonous fossilization.

The last two materials from the *Haku* member are excluded from the present study. Other information as to the occurrence will be seen in the section "Description of the Permian Kuzu Spongiostromata" in this text.

* For instance, there were found several such remains at the 7 th quarry of Karasawa (attached to the Joban Mining Co.).

The algae-bearing beds have been dated as upper Lower Permian on the basis of fusulinids occurring at the surrounding beds (YAMADA, FUJIMOTO, and YOSHIDA, 1951; YAMADA and FUJIMOTO, 1953). According to the students of fusulinids, the *Nezu* member is referable to the "Zone of *Parafusulina*" (cfr. p. 454 in this text).

Description of the Permian Spongiostromata from Kuzu

It is now believed that the Spongiostromata are formed by the activities of algal aggregates, which may consist of several symbiotic or commensal species of the Cyanophyceae, or even partly Cyanophyceae and Chlorophyceae*. So, one may hesitate to deal with such algal products by aggregates under a single generic or specific name, except as a matter of convenience. However, the Paleozoic Spongiostromata do not preserve either the delicate sheaths of the original algae or molds of them.** The Kuzu form is by no means an exception on this respect; hence the author hesitates to give any taxonomic description.***

The Spongiostromata of the lowest horizon with associated brachiopods and foraminifers form a biostrome about one meter thick, the basal part (A-horizon in text-fig. 2) about 30 cm thick is exclusively composed of the gregarious algal colonies, aligned on bedding plane. However, the Spongiostromata occur sporadically in the B-horizon (Text-fig. 2).

Description:—Remains rather flat, depressed, nodular to hemispheric, often, cabbage-shaped; sometimes colonies are so closely crowed that they take diverse shapes by fusion of two or more simple forms. Apparent dichotomy thus derived was occasionally observed.

Vertical section:—subelliptical, or less commonly a dichotomizing cabbage form (Fig. 1 on plate XXIX) concentric lamellae visible, being convex upwards and finely crumpled on a small scale.

Transverse section:—concentric subcircular in outline, 3 to 8 (5 in average) cm. in shorter diameter, and lacking mammilae. Lamina 0.08 to 0.23 mm thick, undulatory in section, sometimes overlapped successively and ramified at some points, composed of calcite, clear to pale brownish colored, some accessory ferruginous mineral, probably limonite. No fine structure suggestive of the original algal sheaths observed. Two successive laminae develop a protuberance above the enmeshing point.

The colony develops around one or more fairly large nuclei; these are commonly fragments of calcareous sponges (Fig. 2 on plate XXIX), less commonly fusuline tests, crinoid stem-joints, brachipods, or rock fragments (Fig. 3 on plate XXIX). The interspace between laminae are filled with brownish gray, highly

* Some authors are of the opinion that they are formed by the activities of the Schizophyceae.

** Exceptions; *Bevosolen* PIA, 1940 (nom. nud.), "Cryptozoons" of JOHNSON, 1946, and several forms of ANDERSON, 1950).

*** There are many form genera in this group; for example, *Anticonophyton*, *Archaeozoon*, *Aphrostoroma*, *Artophycus*, *Atikokania*, *Aulophyctus*, *Camasia* (?), *Chondrostroma*, *Codonophycus*, *Collenella*, *Collenia* *Conophyton*, *Corypodium*, *Copperia*, (?), *Cryptophycus*, *Cryptzoon*, *Evinospongia* (?), *Gallatinia*, (?), *Gouldinia*, *Greysonia* (?), *Gymnosolen*, *Hydrophycus* *Katangasia*, *Kinneyia* (?), *Leptophycus*, *Malacostroma*, *Microweedia*, *Morania*, *Newlandia* (?), *Phormidioidea* *Pycnostroma*, *Shermanophycus*, *Spongiostroma*, *Stenophycus*, *Stromaria*, *Stromatactis*, *Stylocodium*, *Stylophycus*, *Tetonophycus*, *Thaumatophycus*, *Weedia*, *Wingia*, etc. Some authors also include *Osagia*, *Ottonosia*, and *Somphospongia*.

carbonaceous material, enmeshing sponge spicules, minor foraminifers (Fig. 5 on pl. XXIX), bryozoan fragments, "hydrocoralline? of NEWELL et al. (1953)", etc.

Because of no development of digitate, subcylindrical or cylindrical, and subconical column, the Kuzu form could be called a "*Pycnostroma*" (GÜRICH, 1906, p. 38–40), if desirable. The colonies of the Kuzu Spongiostromata are smaller in size than most the Early Paleozoic Spongiostromata, and resemble the "Cryptozoons" described by JOHNSON (1946) from the Pennsylvanian and Permian of Kansas, U.S.A., which, however, preserve some of microstructure of algal sheaths, according to him. The surface convexity indicates that the present bottom-top relation is original.

Inferred Sedimentary Environment of Kuzu Spongiostromata

It has been said that the Nabeyama formation is a deposit in the Later Paleozoic Chichibu eugeosyncline. The algal beds at Yamasuge associate with the thanatocoenose of such marine organisms as foraminifers, calcareous sponges, crinoids, brachiopods, gastropods, etc. The algal colonies commonly grew over them or enmesh them between laminae. This suggests that the algal beds were deposited under a marine environment.

The host rock is a bituminous, autochthonous, calcilutite with thinly interbedded streaks of calcareous shale, without any oölitic texture. These features suggests poor circulation-stagnancy- or weak agitation of the water. In the biostromatic algal beds, the algal colonies usually are not associated with numerous fusuline tests, although a few are present. This suggests very feeble current action, i.e. protected water condition.

The nuclei of the algal colonies are commonly fragmentary calcareous sponges which today prefer a shallow, calm water habitat.

It might not be superfluous to point out that the Spongiostromata grow only at depths where the sunlight could penetrate and photosynthesis is active. As to the maximum depth at which stromatolites are formed, CLOUD (1942, p. 17) referring to the opinions of PARR, SMITH, and HUTCHINSON states that "stromatolite-forming algae will not ordinarily flourish below a depth of about 30 meters in marine waters——."

Since the Tertiary and Recent stromatolites and their related "algal biscuits" have been reported mostly from fresh to brackish water deposits, it has been stated that "since the Paleozoic, they (=stromatolites) have been characteristic of fresh and brackish rather than marine water (NEWELL et al., 1953, p. 11, 201)." PIA (1937) was of the interesting opinion that "während sie (Spongiostromata) aber in Unterkarbon noch durchwegs in normalen meerischen Absaetzen gefunden werden, waren sie in Perm vorwiegend auf Binnengewasser mit vermindertem bisfehlendem——vielleicht manchmal auch er hohem Salzgehalt behalt beschrankt." It has been generally overlooked, however, that the stromatolites are sometimes found associated with marine fossils from Cambrian to Jurassic or even Recent deposits. For instance, all those recent reports on the Spongiostromata from the Anthracolithic of U.S.A. (JOHNSON, 1940–45) are from normal marine deposits (Table 1), perhaps close to the *Nezu* member of the Nabeyama formation under discussion. So PIA's hypothesis seems to have little support, though it is still attractive for us as problem of Late Paleozoic geohistory as well as of the stromatolitic ecology. And, we cannot use the Spongiostromata as a definite salinity index.

Thus, it is concluded that the Kuzu Spongiostromata were formed under a marine environment where stagnant water was prevailing, the depth not exceeding some 30 m. (probably less), and salinity possibly a little lower than normal marine due to constant inflow of fresh water. A tidal lagoon may be the closest among the Recent environments which is comparable with this environment. This environment did not last very long and changed very shortly.

This conclusion contradicts the common opinion that the stromatolites usually need a disturbed water to grow. However, there are reports of fossil stromatolites from a calm environment such as logoonal phase (e.g. REYNOLD, 1921, p. 226, Spongiostromata at S_1; MILON, 1933, p. 71; GARWOOD, 1931; etc.). GINSBURG (1955) recently noted that "small discrete spheroid forms" probably like the Kuzu form of Recent oncoliths from a "protected water 1–6 feet" deep in South Florida.

Record of Permian Spongiostromata

The records of the Permian Spongiostromata are summarized as the table 1.

TABLE 1

* Nodulea resembling very closely Spongiostroma	Base of the Permian near Maxstoke, England	GARWOOD, 1913, p. 549
* "Knollige order brotleibformige Kalkmasse, an Gymnosolen erinner Asten zusammengesetzt sind"	Ottweiler and Kuseler fmts. (Uppermost Carb. to Lowest Perm.) in Rothliegend at Rhein Plateau, Germany	REIS, 1903, 1913, etc. (PIA, 1937, p. 817)
? Stromatolithe	Lower Zechstein, Germany	ERNST, 1931, (PIA, *ibid.*, p. 818)
* *Pycnostroma*	Tartarian (Uppermost Perm.) at the mouth of Veshnja Erga in Sukhona, U.S.S.R.	PIA, 1931, (PIA, *ibid.*, p. 818)
Collenia uralica MASLOV	Lower Permian of South Ural, U.S.S.R.	MASLOV, 1935, (PIA, *ibid.*, p. 819)
Five groups of problematica (*Weedia*, *Archaezoon*, and *Gymnosolen* after PIA, 1937)	Sakamena fmt. of Karroo group (Uppermost Perm. or Neo-Perm. to Eo-Trias.), Madagascar	BRIERE, 1923, p. 127–32, 3 pls.; BESAIRE, 1932, p. 132; SAVORNIN, 1932, (PIA, *ibid.*, p. 818)
Stromatolithes	Sakao group of Karroo system, Madagascar	BESAIRIE, 1952, p. 181
° *Cryptozoon wrefordensis* JOHNSON	Wreford ls, Cowley co., Kansas, U.S.A.	JOHNSON, 1946, p. 1107, pl. 10, fig. 1
° *Collenella guadalupensis* JOHNSON	Carlsbad Caverns, Yates fmt., Guadalupe Mts., New Mexico, U.S.A. (lagoonal dolostone)	JOHNSON, 1942, p. 212, pl. 7, fig. 3; NEWELL et al. 1953, p. 152
	Capitan reef ls., Walnut Canyon, Caverns National Park, New Mexico, U.S.A.	NEWELL et al., 1953, p. 111, etc. pl. 17, fig. 2, pl. 20, fig. 2
° Pisolitic masses	Guadalupe Mts., New Mexico, U.S.A. (lagoonal facies; shelf area)	JOHNSON, 1942, p. 213; NEWELL et al., 1953, p. 120, 143, etc.
° Spongiostroma	Zone of *Polydiexodina*, Apoche Mts., Texas, U.S.A.	JOHNSON, 1951, p. 29
° Laminated encrusting stromatolites, biscuits or rounded cabbage masses etc.	Capitan reef limestone, Guadalupe Mts., New Mexico and Texas, U.S.A.	NEWELL et al., 1953, p. 112, 177, pl. 18, fig. 3

* Non-marine ° Definitely marine

The structures like WALCOTT's Algonkian algae (*Newlandia*-, *Copperia*-types) described by HOLTEDAHL (1921, p. 195–206, 8 text-figs.) from the Permian magnesian limestone of the Durham district, England, are excluded (FENTON, 1943, p. 93).

Some Cretaceous Problematica might be Referable to Fossil Algae

1. Kwanmon group in Western Japan.

In 1936, Kobayashi reported the "*Cryptozoon*-like fossils" from the "Inkstone series" cropping out along the coast, west of Yoshimi, Toyonishi village, Yamaguchi Prefecture. As summarized by Matsumoto (1953), the term Kwanmon group is applied to the Inkstone series which is reclassified into two subgroups, the lower, Wakino, and the upper, Shimonoseki. The beds containing the Problematica occur in the transitional part between the subgroups (cfr. Matsumoto et al., 1953, pl. 13, p. 164). The objects were called "calcareous concretions and smaller lenses of pisolite-like limestone" (Matsumoto, ibid.). Under the kind guidance of Mr. Ueda, the author visited the locality and observed their mode of occurrence.

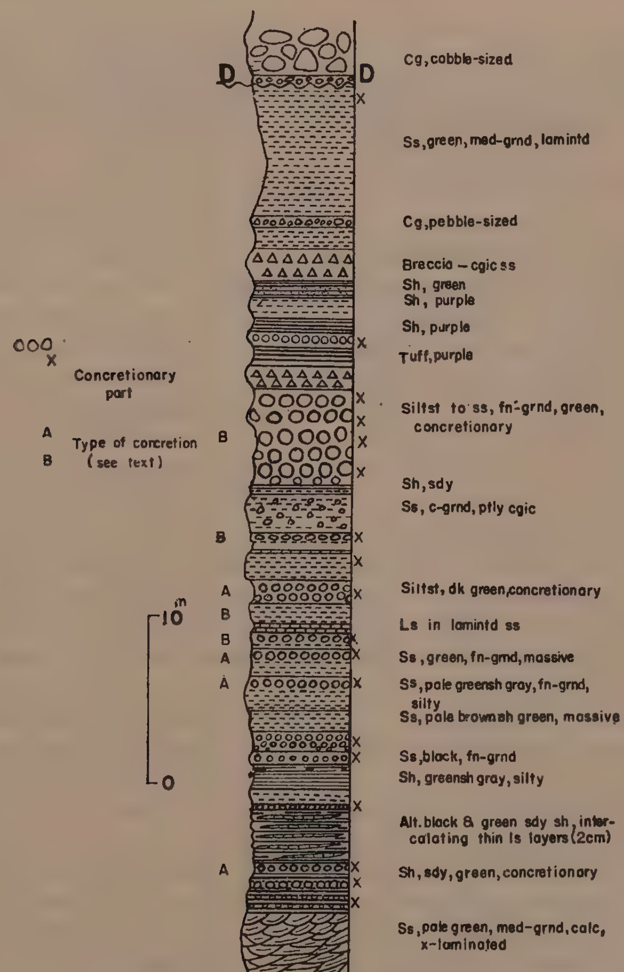

Fig. 3. Kwanmon Group Section along West of Yoshimi

D on this columnar section is the basal unit of d′ by Matsumoto et al. (1953, p. 164). The reader is requested to refer to the description on p. 164 and plate XIII for further information.

As shown in text-fig. 3, there are some ten horizons containing the concretionary objects. They occur as ophthalmites in the pale greenish calcareous muddy to fine sandy rocks. In some beds they occur in the upper half of each stratum, just below a bedding plane. Their forms are highly variable; elliptical, subspheroidal, spindrical, or even cabbage-shaped, but two forms are arbitrary distinguished by the characters shown below.

Form / Character	A	B
Shape	Usually well rounded	Usually much irregular, cabbage-like mammilate
Size (longest axis)	Less than 5 cm in average	Usually more than 5 cm
Structure	Structureless	A few concentric laminae recognizable at the outermost crust, ca. 5 mm. thick
Occurrence	Uniform density, independent of crowding and scattering	Rather heterogeneous, either localizing crowded or scattering, even within a bed
Host rock	Silty (tuffaceous ?)-soft	Calcareous fine sandstone-hard

As the macrofeatures in common both the A- and B- form, are also discernible the lacking of the exotic nucleus and of "algal" crustose structure, and the restricted occurrence in or close to the lime-rich beds, and in the upper half of each of the beds concerned. The author is inclined to refer the differences cited above to that of the host (or original) rocks and to believe that the A-form is merely a variant of the B-form, after he has examined and described microscopically.

The microscopic observation of the B-form did not show any definite "algal structure." The very contact between the object and the matrix (host rock) is often obscure. Lithologically, there is a slight difference in the texture of the both, but not in the mineral composition; both are composed principally of quartz, calcite, chlorite, seldomly of such accessories as zircon, tourmaline, and chalcopyrite. The angular quartz grains are common. The relative amount of calcite to quartz is considerably different between the object and matrix; the matrix is termed fine sandstone, while the concretion is calcareous shale (very fine sandstone), calcareous chert or calcareous porcellanite, associating with mosaics of chalcedonic quartz. Two or three alternating crusts at the outermost part of the concretion, each 0.8 mm. thick, are composed of the same minerals as those of the internal core. This feeble crustose structure corresponds to the change of the relative amount of calcite to quartz.

Thus, the author fails to observe any conclusive evidence to refer the Yoshimi form to the Spongiostromata; all the evidences seem to support its reference to the concretionary, most probably epigenetic, structure. He is of the opinion that the grain size and texture of the host rocks are responsible for the difference of permeability and hence of appearance of the epigenetic concretion. However, it is not possible at present to exactly determine its origin and the possibility as a byproduct of photosynthesis by some primitive aquatic plants is not entirely excluded. Further studies using isotope chemistry might be able to solve this type of problem.

Besides the Yoshimo locality, the author visited the summit of Mt. Kazashi, Moji City, Northern Kyushu, where similar concretions were noticed by field geologists. As shown in figure 7 on plate XXX, the concretions occur on weathered surface as cobble- to pebble-sized cavities or notches, white to pale greenish in color, aligned their longer axes regularly, as if to suggest the original stratification of the host rock. There are a few examples suggestive of a mammilate-like structure, and some appear to have a cabbage-form, bnt no definite algal structure could be observed. Actually, the rocks around the Mt. Kazashi were so thermally metamorphozed during the Cretaceous and Early Tertiary, the concretions are epidote-calcite rocks and the host rock biotite-hornfels. It is mentioned that the Kazashi locality is assigned to the upper part of the Wakino subgroup (MATSUMOTO et al., op. cit., p. 161, pl. XII), so that may be nearly correlative with the stratigraphic position of the Yoshimi locality.

2. Kyoengsang group* in South Korea.

It is noteworthy that KODAIRA (1922) and TATEIWA (1929) reported "reef algae" from two formations in the Kyoengsang correlative with the Japanese Kwanmon group. The following outline of the reef algae in South Korea is based on their works. No specimens were available for study.

1) Shinshu formation*, Naktong group by TATEIWA (Chinjyu series by KODAIRA; cfr. MATSUMOTO et al., op. cit., p. 166)

Reefs have been reported from the mudstone beds of the upper Chinjyu series of the Naktong group (lower Kyoengsang group) on the western cliff of Manchin-sanmen, Chinjyu, and also on the cliff of the eastern side of Chinjyu (KODAIRA, *ibid.*, apend. 1; TATEIWA, *ibid.*, p. 3 in Japanese text). KODAIRA named the reef-building algae *Nematophycus orientalis* sp. nov., which is a *nomen nudum.* A summary of KODAIRA's description is:

External form:—Nodular, large—the largest some 3 m. long and 0.17 m. in the maximum diameter; the smallest some 1 m. long 0.005 m. in the minimum diameter—; irregularly branched, cylindrical, gray in color, with distinct concentric bands on weathered surface.

Microstructure:—Branching short radial lines across the concentric rings. Algal sheaths, two kinds; 1) simple tube, 10–25 μ in diameter (mostly 17 μ) scattering in dark matrix and sometimes placed in direct contact, and 2) small interstitial, irregularly branching tubes 2–3 μ in diameter, occupying some of the space between the larger tubes.

Host rock:—Compact and hard calcareous gray mudstone, somewhat recrystallized secondarily. No other organic remains are recognized.

Occurrence:—See text-fig. 4 in this paper.

2) Taikyu formation, Shiragi group (TATEIWA, *ibid.*, p. 4; cfr. MATSUMOTO et al., *ibid.*, p. 171)

TATEIWA recorded a "remarkable fossil algal reef" from the deep gray shales and peats of the middle part of the Taikyu formation on the right bank of the River Kinkoko near Onkodo, about 4 km southwest of Kaiyo, Eisen district, North Keisho-do. But he did not name it. The specimens from the reef were sent to Dr. YABE and studied by him. He kindly informed the author that he found

* According to the current terminology adopted by Geological Survey of Korea, the "Kyoengsang system" is divided into,

b) Silla series; cg., ss., sh., tuff, and porphyrite; terrigenous and volcanics; 3,000 m. thick.

a) Naktong series; mudst., ss., and cg.; terrigenous; 4,500 m. thick.

"some fungi-like" microstructure which, however, might be merely cracks secondarily derived.

Judging from KODAIRA's description and illustration, it is most probable that the Cretaceous form is not a *Prototaxites* DAWSON 1859, which is synonymous with *Nematophycus* CARRUTHERS, 1872, a possible Phaeophyceae during Siluro-Devonian. It is, however, still possible that the Cretaceous form represents a product of some commensal algae. Contrary to the Japanese Cretaceous material, then, these two Korean forms are of particular interest because of their possible algal character.

It has been said that the Naktong group is lacustrine deposits like the Wakino subgroup and the Taikyu formation* (e.g. KOBAYASHI and SUZUKI, 1936; cfr. MATSUMOTO et al., op. cit.), because of its lithology and fossil content. Locally the rocks of the Shinshu formation (text-fig. 4) show several beds with ripple marks and cross-lamination, and considerably high sand-shale ratio (0.71). The occurrence of *Brotia wakinoensis* just above the middle horizon of the Problematica under discussion indicates a free-circulating, non-marine, perhaps lacustrine, environment. The conclusion recalles CLOUD's statement that "the fresh water stromatolites may be grown in depth less than 10 meters (1942)."

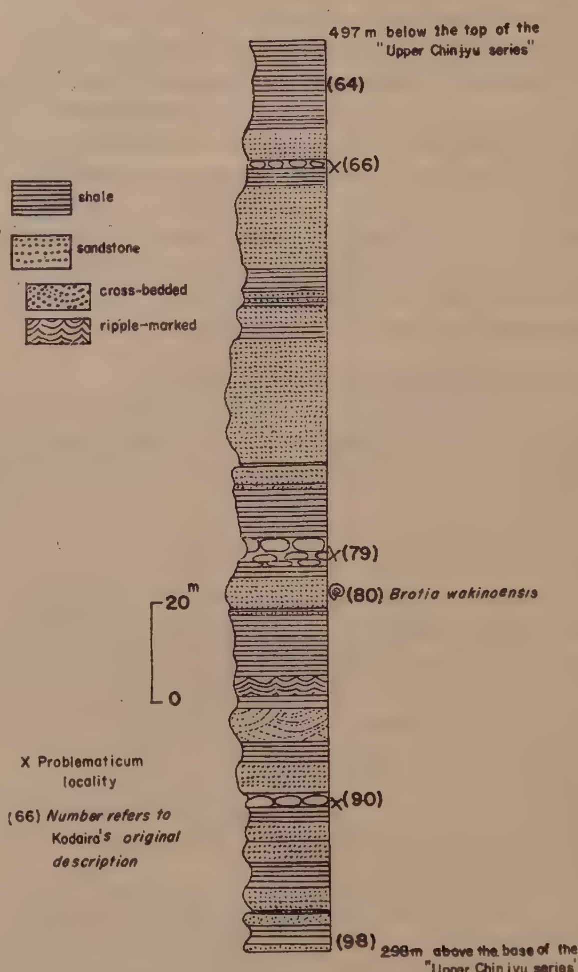

Fig. 4. Lower Part of "Chinjyu Series (Upper)" Indicating Position of Occurrence of Korean Problematica (Data from Kodaira, 1922)

Notes on *Anthracoporella spectabilis* PIA, associating with the Kuzu Spongiostromata

Among the Permian Kuzu algal florule, the author has selected the dasycla-

* A very shallow non-marine environment is certainly inferred on the basis of the beds with ripple marks and sun-cracks in close to algal reef of the Taikyu formation.

dacean *Anthracoporella spectabilis* PIA, which is familiar with European geologists, in order to indicate its role as an index fossil.

Genus *Anthracoporella* PIA, 1920

Anthracoporella PIA, 1920, p. 15–18, pl. 1, figs. 7–11, text-fig. 3; PIA, 1927, p. 63, text-fig. 40.

Diagnosis:—Dasyporelleae with ramified thallus and once or twice bifurcated lateral branches.

Accredited Species:—

A. spectabilis PIA, 1920 (Type Species)

A. magnipora ENDO (1952)

Distribution:—Uppermost Carboniferous (?) to Permian (probably Lower), southern Europe, Iranian Baluchistan, and Japan.*

Anthracoporella spectabilis PIA

Plate XXXI, Figs. 14–23; Text-fig. 5

Stollayella velebitana NEGRIAS, 1919, Roches cristallophylliens et tectonique de la Grece, p. 215.

Stolleyla velebitata NEGRIS, *ibid*, pl. 26, figs. 3–4.

Anthraeoporella spectabilis PIA, 1920, *Zool.-bot. Gesell. Wien, Bd. 11, Hft. 2*, S. 15–18, pl. 1, figs. 7–11, text-fig. 3.

Anthracoporella spectabilis PIA, 1927, *Handbuch der Palaeobotanik*, p. 63, fig. 40

Anthracoporella spectabilis PIA, 1928, *Palaeobiologica, v. 1*, p. 220, pl. 21.

Anthracoporella spectabilis PIA, 1928a, *N.J.M.G.P.*, S. 231.

Anthracoporella spectabilis PIA (not *A.* cfr. *spectabilis* JODOT) in JODOT, 1930, *Bull, soc. geol, France, 4 ser., t. 30*, p. 521, text-fig. 2.

Anthrocoporella spectabilis PIA, 1936, *Probl. Paleont., v. 1*, p. 25.

Anthracoporella spectabilis PIA, 1937, *C.R. 2e Congr. strat. carbon., Heerlen, 1935, t. 2*, p. 809–810, 816.

Anthracoporella spectabilis DOUGLAS, 1950, p. 4 (identified by A.G. DAVIS)

Anthracoporella spectabilis ENDO, 1952a, *Trans. Proc. Palaeont. Soc. Japan, N.S., No. 5*, p. 139–40, pl. 12, figs. 6–7.

Anthracoporella spectabilis ENDO, 1952b, *ibid., No. 8*, p. 244, pl. 23, fig. 1

? Algenkalk HERITSCH et al., 1933, *Mitteil. Geol. Gesell. Wien. Bdn. 26-27*, S. 170–171.

Material:—The material was procured from three localities; 1) northern slope, north of the second quarry in the first factory of the Joban Mining Co. at Aisawa (black limestone cropping out 8 m. below the base of the *Dolo* member, 2) bituminous limestone bed 5 m. above the A-horizon at Kurakakeyama section (Text-figs. 2 and 3) 5 m. below the base of the *Dolo* member, about 100 m. northwest of the terminal of the cable at the mouth of Aisawa. It is obvious that all the localities are located within the *Nezu*, particularly its upper part, of the Nabeyama formation.

Observation:—Based upon fragmentary weathered specimens (Figs. 22 and 23 on plate 3), and some longitudinal thin sections, it is evident that this alga appears bushy, highly branched, as "Dendrida inarticulated," and irregularly constricted, often bifurcated (cfr. PIA, 1928, pl. 21). Some thalli are very coherently fused each other. The texture of the host rock indicates the primary nature of this

* There has been reported *Anthracoporella* without either description or illustration from the "Groupe de la Sakamena" and "Groupe de la Sakoa" in Madagascar. The generic assignment of this *Anthracoporella* is open to question.

close packing. The Kuzu *Anthoracoporella* is an autochthonous rather than allochthonous as to its fossilization; a mode of fossilization of Dasycladaceae seldom seen in the Paleozoic deposits of Japan.

Fig. 19 on plate XXXI shows the bifurcating thallus cut tangentially (angle ofdichoto my about 70 degrees). The other is Fig. 21 on the same plate, in which the proximal part shows a growing bud emerging from the stem.

The transverse sections are circular or semicircular in outline. Size frequency of the external diameter is shown in text-fig. 5 together with that of the diameter of central stalk. The histograms indicate a simply normal distribution, instead of lognormal like *Gymnocodium kanmerai* KONISHI (1954).

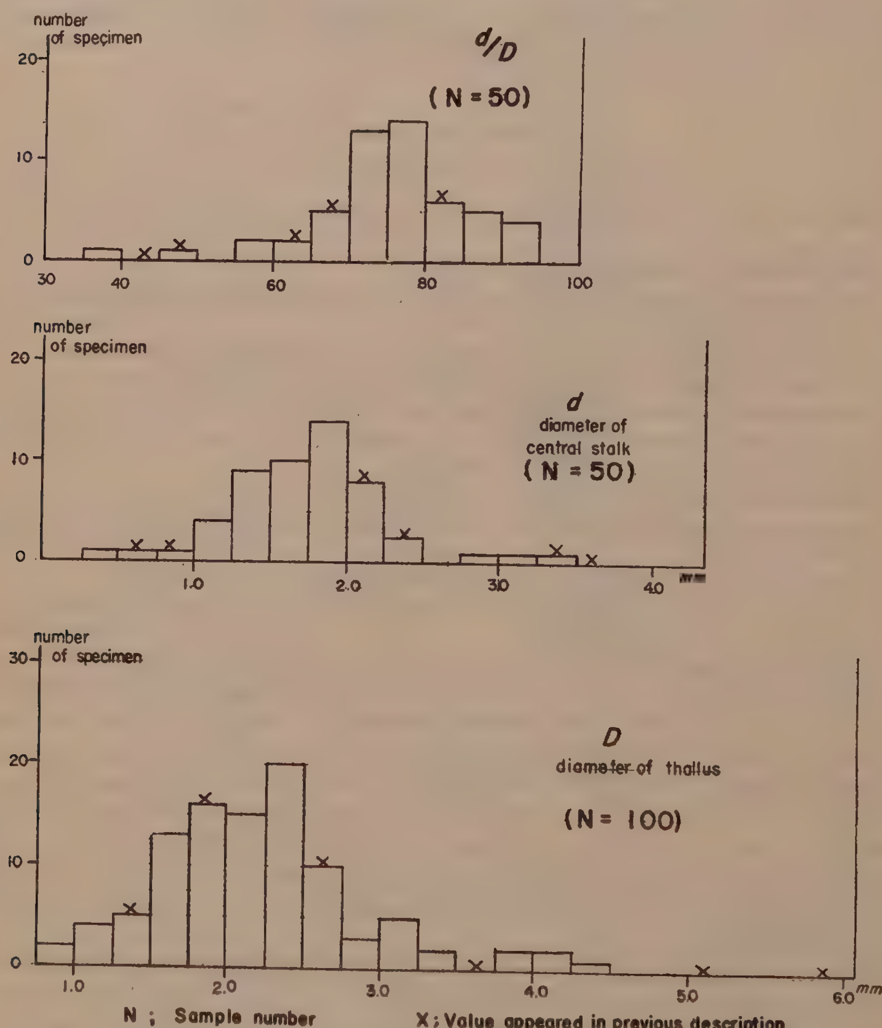

Fig. 5. Measurement of *Anthracoporella spectabilis* from Kuzū

As shown in text-fig. 5, the size of the central stalk is variable, though, in general, the ratio d/D is fairly consistent within the range from 70 to 80%. Al-

though the author is inclined to refer this large diameter of the uncalcified central cavities to a matter of preservation which may be quite variable even within a single species, it is still ambiguous that whether this form had a thick central stalk or a medium-sized one with only partly—peripherily—calcified sheath.

The lateral branches are simple with little change of diameter. They are perpendicular to the surface. In longitudinal sections, they are spaced fairly regularly with intervals of 57 μ within the thin (e.g. 250 μ) outermost calcified cortex. Because of poor preservation, the exact number of the lateral branches on a whorl could not be counted, but, if a restoration shows, it may have reached 150 or slightly more. On the surface about 130 outlets of lateral branches occur in a square of 1 mm. square, spaced at intervals of 74–75 μ, measured on tangential sections.

Comparisons:—Among the Dasycladacean genera, only *Vermiporella* and *Anthracoporella* can be compared with the form under question, because of their branching thalli. Most the Kuzu specimens preserve unramified lateral branches which are a characteristic of the first genus, and only a few show the ramified branches, which suggest the second genus. However, thallus-size, number of lateral branches on a whorl, and other quantitative characters are another points of difference between the two genera, and, in these respects, the Kuzu form belongs to *Anthracoporella*.

Two named species and three unnamed forms have been referred to the genus. The unnamed forms described by JOHNSON (1942, p. 209, pl. 5, fig. 5; 1951, pl. 7, figs. 6–7, p. 24–25) are unique for the genus in having ill-defined central cavities and very small number of the lateral branches on a whorl, so that they are left beyond the present comparison. The third unnamed form is mentioned from the Karroo series (particularly abundant at the basal part of the Sakamena group, though it is known from the Sakoa group, too). The identification was made by PIA, but the result was never described paleontologically, so that no comparison is possible with this form.

A. magnipora ENDO (1951) has larger diameter (100–180 μ) of outlets of the lateral branches and a smaller number in a whorl (about 45) than *A. spectabilis*. As far as the size variation is concerned, thus, the Kuzu form almost coincides with the type species of the genus except the ill-defined ramification of the lateral branches. The range of D and d coincides with that of PIA's original diagnosis; although the ratio d/D is more consistent and in average more larger in the Kuzu form than the European form (48–83%; PIA, *op. cit.*, p. 15). Actually, fig. 10 on pl. 1 of PIA (1920) is identical with the Kuzu form in the preservation of apparently unramified lateral branches and considerably broad central stalk. Following his broad concept of this species, the Kuzu form is identified as *A. spectabilis*.

Dating:—The species was long said to be an Upper Carboniferous guide fossil (PIA, 1920–36), then from Upper Carboniferous to Lower Permian (PIA, 1937; EMBERGER, 1944). The localities where PIA reported the occurrence of the species are; 1) Carnic Alps; 2) Karavanke, Yugoslavia, and 3) Chios Island, Greece. Most of the Alpine localities are inclusive in the lower Rattendorf formation which HERITSCH referred to a basal Permian member (cfr. PIA, 1937). Even if some localities were included in the Auerning formation which HERITSCH considered as Uppermost Carboniferous (cfr. GERTH, 1950), and also, if the "Algenkalken" of the "oberen kalkreichen Schichtgruppe" by HERITSCH et al. (1934, p. 170–171) are referable to *Anthracoporella*-limestone of PIA (1937, p. 809), it should be men-

tioned that the beds of the black fusuline limestone (Schichte g, 96, 97; 12 m. thick) yielding *Schwagerina alpina* var. *antiqua* (SCHELLWIEN) lies 3 m. or less below the lower "Algenkalk" above-mentioned. This fusuline genus undoubtedly is a characteristic element of the Lower (Basal) Permian; the Uppermost Carboniferous age of this "oberen Kalkreichen Schichtgruppe" is probably not consistant with the fusuline data.

The horizon where the Karavanken materials were obtained has been correlated with a part of the Trogkofll limestone (PIA, 1937, and others) which belongs to the Zone of *Parafusulina*. The Greek niveau is also Permian rather than Upper Carboniferous, judging from the association of *Mizzia velebitana*, as the case of the Iranian Baluchistan (DOUGLAS, 1950).

In Japan, ENDO (1952, 52a) has recently reported this species from the two different horizons, one of which is upper Visean Onimaru "series" at Sakamotozawa, southern Kitakami Mountainland, and the other is "*Triticites* zone" in the Omi limestone group, Central Japan. The Omi material is represented by a sole, fragmentary "longitudinal" section and its details are uncertain. Some fusuline students are casting a doubt if it could be a basalmost Permian instead of Uralian or "*Triticites* zone (s. str.)." Since all the beds on which the applicability of *A. spectabilis* for an Upper Carboniferous guide fossil has been founded are now referred to the Lower Permian, the Visean occurrence may be an open question. The present author has studied a sizable collection of the Pennsylvanian as well as Mississippian limestones of the Southwestern Japan, and has not yet found *Anthracoporella* in it.

Thus, the author is of the opinion that the epibole of *Anthracoporella spectabilis* is in world—wide Lower Permian—Zone of *Pseudoschwagerina* and *Parafusulina* —rather than Carboniferous. The forerunner might be traced back to Uppermost Carboniferous, though the Mississippian occurrence* is an open question. The use of this alga for further detailed dating may be impossible. The fusuline associaties in the *Nezu* member determine the stratigraphic position of *A. spectabilis* to be Lower Permian, the *Pseudofusulina—Parafusulina* Zone (HANZAWA, 1942; YAMADA, FUJIMOTO and YOSHIDA, 1951) as in Southern Europe.

Postscript:—According to the recent publication by ELIAS (1957), "Russian geologists draw the Carboniferous-Permian boundary at the base of the Artinskian as before [!] and not at the base of Sakmarian where most American geologists place it. It appears that this is geologically expedient for the Russians, particularly in subsurface correlations ...... and is followed officially by Russian geologists." The term Permian used in this paper is followed to the Japanese as well as American usage.

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* As to JODOT's "*A.* cfr. *spectabilis*" from the "Dinantian" of Corse, the author agrees with PIA (1937, p. 795).

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K. Konishi

Notes on some Japanese Permian and
Cretaceous Algae and their
Stratigraphic Setting
(Studies on the Paleozoic Marine Algae of Japan—4)

Plate XXIX

Explanation of Plate XXIX

Figures 1–5. *Pyenostroma*-type Spongiostromata from Permian Nabeyama formation, Yamasuge, Kuzu, Central Honshu.

Figure 1. Vertical section on weathered surface; indicates dichotomous cabbage growth form. (×1) Locality A on text-fig. 2.

Figure 2. Transverse section (polished); the nuclei are calcareous sponge. (×1) Same locality as the above.

Figure 3. Transverse section (polished); the nucleus is a frogment of calcilutite. Same locality as the above.

Figure 4. Weathered feature on bedding plane (almost nearly transvese sections). (×1/8) Same locality as the above.

Figure 5. Cross thin section of encrusting laminae; minor forminifer (*Tetrataxis*) is enmeshed between laminae (lower right-hand corner). (×40) Same locality as the above.

Figure 6. Inorganic pisolites from Cretaceous Wakino subgroup, Hanaoyama, Yamaguchi, Western Honshu. (×1)

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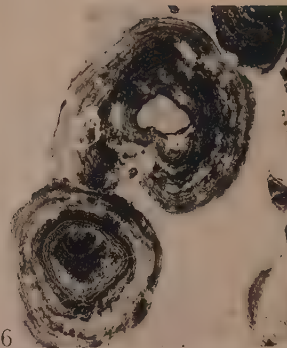

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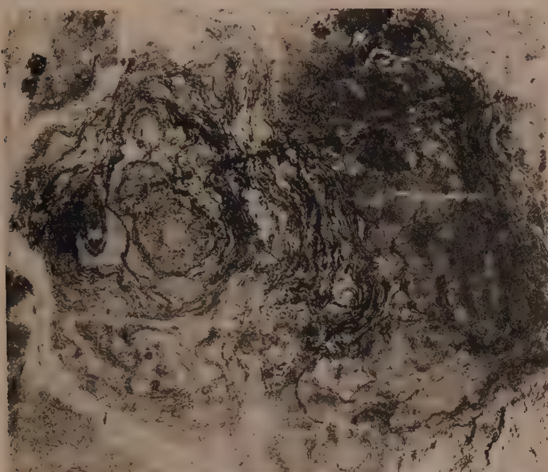


2

3

4

5

K. Konishi

Notes on some Japanese Permian and
Cretaceous Algae and their
Stratigraphic Setting
(Studies on the Paleozoic Marine Algae of Japan—4)

Plate XXX

Explanation of Plate XXX

Figures 7–13. Concretionary structure in Cretaceous Wakino subgroup, Yoshimi, western Honshu and Kazashi-yama, northern Kyushu.

Figure 7. Pebble-sized cavities on the weathered surface. (see text p. 000) Kazashi-yama, Moji City, northern Kyushu.

Figure 8. Type B concretion, occuring on calcareous phase. Yoshimi section, western Honshu.

Figure 9. Purely calcareous concretions making a thin layer within silty beds. (×1/12) Yoshimi section.

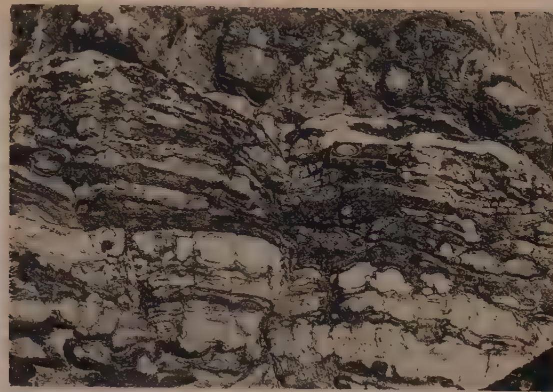
Figure 10. Large example of Type A, occurring within silty rock. Yoshimi section.

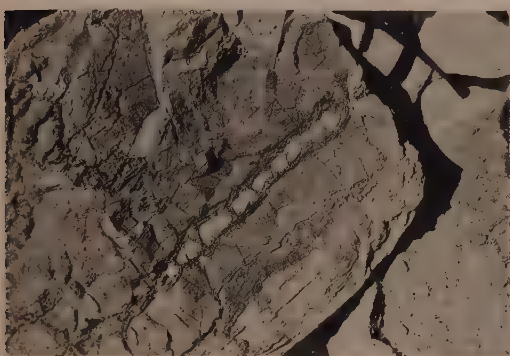
Figure 11. Typical Type B within calcareous sandstone. Yoshimi section.

Figure 12. Type B, showing crustose structure. (×1) Yoshimi section.

Figure 13. Internal structure (polished) of type B. (×1) Yoshimi section.

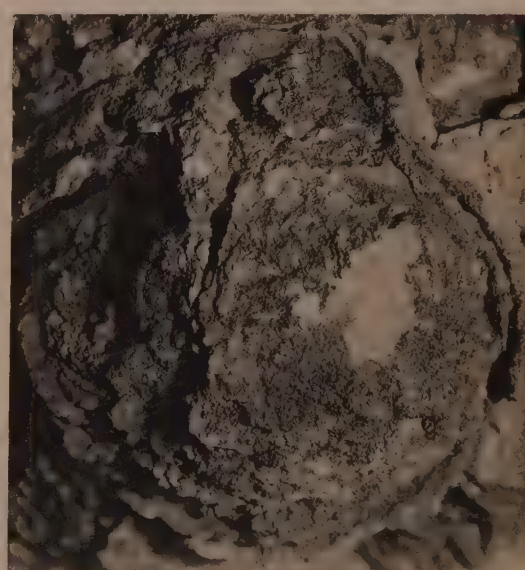

7

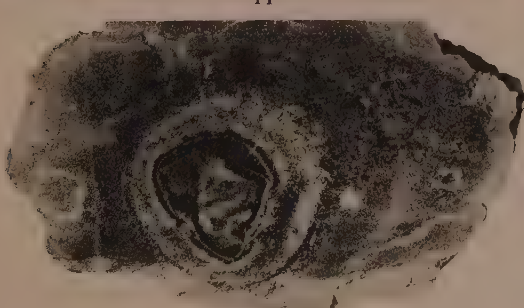

8


9


10


11


12


13

K. Konishi

Notes on some Japanese Permian and
Cretaceous Algae and their
Stratigraphic Setting
(Studies on the Paleozoic Marine Algae of Japan—4)

Plate XXXI

Explanation of Plate XXXI

Figures 14–23. *Anthracoporella spectabilis* PIA from Permian Nabeyama formation, Kuzu, central Honshu.

Figure 14. Slightly oblique cross section. PP 7255: slide 54051015–9, Aisawa. (×10)

Figure 15. Cross section with thin calcified wall. PP 7257; slide 54051016–7, Aisawa. (×10)

Figure 16. Cross section with calcified central stalk. PP 7258; slide 54051016–8, Aisawa. (×10)

Figure 17. Cross section. PP 7259; slide 54051016–12, Aisawa. (×10)

Figure 18. Oblique section suggesting dichotomous thallus. PP 7256; slide 54051015–11, Aisawa. (×10)

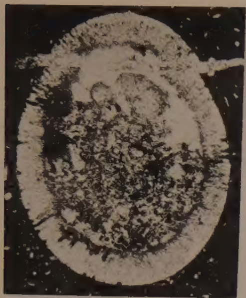
Figure 19. Tangentially longitudinal section indicating the dichotomous thallus. PP 7252; slide Ym–1–1, Yamasuge. (×10)

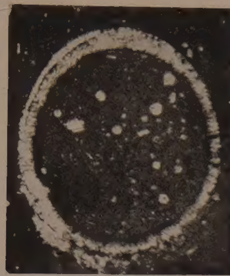
Figure 20. Oblique section. PP 7254; slide 54051015–8, Aisawa. (×10)

Figure 21. Longitudinal section of "budding part" of thallus. PP 7253; slide 54051015–7, Aisawa. (×10)

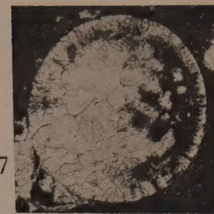
Figure 22. Exposure feature on weathered surface. Aisawa. (×1)

Figure 23. Exposure feature on weathered surface. Yamasuge. (×1)


14


15


16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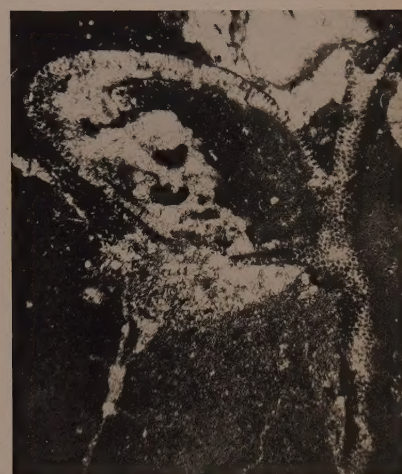
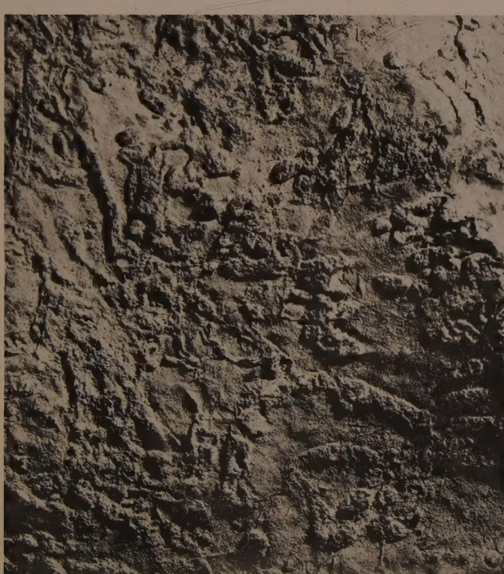
18


19


20


21


22


23

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